An Elementary Course in Biology

Pillsbury

A

LABORATORY GUIDE

FOR

An Elementary Course

IN

GENERAL BIOLOGY.

BY

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SILVER, BURDETT AND COMPANY,

NEW YORK . . . BOSTON . . . CHICAGO.

PREFACE.

THIS little work is not intended as a remedy for ignorance on the part of the teacher, nor as an inducement to indolence on the part of the student, but rather to provide a simple guide to a logical series of elementary studies of typical living organisms, of such a nature as shall enable both teacher and student to accomplish the most desirable results in a given and generally limited time. When the teacher has a small number of students, the necessity of such a guide is less imperative than when, as is usually the case, a large number of students must be directed by one teacher. The author's aim has been to give only a very simple outline of work, to serve as a basis of more full and extended work, to be supplied at the option of the teacher. An effort has been made to supply only such directions as will enable the student to acquire the greater part of his knowledge at first hand, without the loss of valuable time in aimless search. The outlines are the result of a number of years' experience in the laboratory, and it is the hope of the author that they may in some degree lighten the labors of the teacher, and so make a greater efficiency possible.

The outlines of classification are intended only to give some idea of the relations of the groups of which

the form studied is taken as a type. Most teachers will doubtless prefer to modify it in accordance with some of the various authorities in systematic botany and zoölogy, and in all cases it will need to be supplemented by material from other sources. The following books, among many others, will be found of value as supplementary aids to the work: —

Sedgwick and Wilson's "Biology;" Parker's "Elementary Biology;" Bessey's "Botany;" De Barry's "Comparative Anatomy of Phanerogams and Ferns;" De Barry's "Morphology and Biology of Fungi, Mycetozoa, and Bacteria;" Goebel's "Outlines of Classification and Morphology of Plants;" Packard's "Zoölogy;" Brooks' "Invertebrate Zoölogy;" Marshall and Hurst's "Practical Zoölogy;" Howes' "Atlas of Biology;" Claus' "Zoölogy;" Gegenbaur's "Comparative Anatomy;" Lang's "Comparative Anatomy;" Vogt and Yung's "Comparative Anatomy" (German); Hatscheck's "Zoölogy" (German); Ecker's "Anatomy of the Frog;" and Balfour's "Comparative Embryology."

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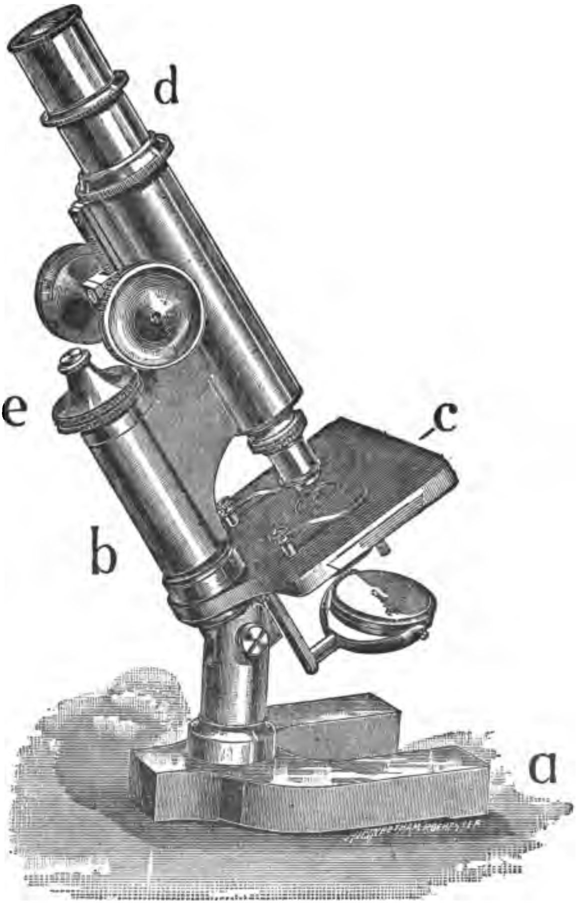
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THE

LABORATORY AND ITS APPLIANCES.

FOR a biological work-room an abundantly lighted room is necessary. The light should come from the north, if possible. A west room in the morning, or an east room in the afternoon, will answer. Direct sunlight is very poor light for microscope work. The room should be supplied with one ample sink, at least. A small sink for every table would be more convenient. A thoroughly ventilated closet, with sink and running water, is desirable for maceration, and an ample room for storing material. Tanks with running water for keeping specimens alive, and abundant glass aquaria for the same purpose, are almost indispensable conveniences for a well-equipped laboratory.

The microscope is the essential instrument of the biologist. Modern biological science was not possible until the discovery of the compound microscope. A knowledge of the principles upon which it works, and the relation of its parts, must therefore precede its use as an instrument of study. It consists of two somewhat distinct sets of parts, the *lenses*, which are the essential parts, and the *stand*, which is the mechanical support of the lenses. The *stand* consists of the *foot* (*a*),

the upright *body* (*b*), the *stage* (*c*), and the *draw-tube* (*d*). The opening through the stage is arranged to be closed with some form of *diaphragm*, to regulate the amount of light that is used to illuminate the object. Beneath this stage is a *mirror*, by which the light is to be reflected through the lenses and the object to be examined. The distance at which the object must be placed for clear vision is called the *focal distance*, and the adjusting of the lens for this purpose is called *focussing* the microscope. This is accomplished roughly by sliding the draw-tube up or down in its socket; and when the object is nearly clear, it is completed by a screw (*e*), which is called the *fine adjustment*.

The most essential part of the microscope is the lenses. These are of two kinds, — the *ocular*, or *eyepiece*, in the top of the draw-tube, and the *objective*, at the bottom, next the object. Each of these may be used in various powers of magnification. These are the most expensive parts of the instrument, and must be handled with the greatest care. Two objectives and two eyepieces, giving a magnifying power of about 50, 100, 250, and 450 diameters, are very convenient for laboratory work. When the lenses are in place, the mirror should be adjusted so as to give a clear circle of white light as you look through the eyepiece. A little practice will enable you to secure this. This clear circle of light is called the *field*, and will vary in apparent size with different powers of eyepieces, and in brightness with the eyepiece and objective used.

To obtain a familiarity with the magnifying power of the microscope, the following plan is a good one. After having adjusted the microscope so as to get a clear white field with the low power, fix the eye upon the right border of the field and raise the head, moving it slowly to the left, so as to keep the edge of the field in view until the eye is ten or twelve inches above the eyepiece. Place a slender rule across the stage of the microscope from right to left under the spring clips, and then hold a pencil upon this at right angles to it in such a position that the inner edge of the pencil as seen over the eyepiece will be on a line with the border of the field as seen through the microscope. When this position is determined, ascertain the position of the pencil upon the scale of the rule, and note it on paper. Do the same thing with regard to the left edge of the field. The difference of these two readings will give you the width of the apparent field taken at the distance of the stage from the eyepiece. If this distance is increased, it will necessarily increase the size of the apparent field.

Place upon the stage of the microscope a glass slide with a scale divided into millimeters and fractions of a millimeter ruled upon it (for the low power objective a card or thin rule with a millimeter scale ruled upon it will answer very well), and ascertain how many divisions of the scale are included in the field. This will give the size of the real field. Divide the size of the apparent field by that of the real field, and the quotient will be the magnification with the length of tube used.

Repeat this process for each of the four combinations of objective and eyepiece, and record it in your note-book for future reference.

Put some small object like pine pollen grains on a glass in a drop of water, and cover it with a cover glass. Examine it with a low power of the microscope. After you have examined it carefully, and think you understand its form thoroughly, make a circle in your note-book of the size which you found by your measurements is the proper one for the combination used, and make a drawing of several of the grains of a size to correspond with the circle drawn.

In addition to the microscope, the student should be provided with other appliances for work. Bottles of alcohol, staining fluids, and various reagents needed, glass slides and covers, dissecting-needles, fine-pointed forceps, a case of dissecting instruments, including scalpel, scissors, and forceps, watch-glasses, and dishes for water, are of first importance. A dissecting-pan with wax bottom, a small dissecting-board, shallow glass dishes, etc., are also convenient.

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GENERAL BIOLOGY.

INTRODUCTION.

IT is necessary, when we are to enter upon the study of any subject, that we should first get a clear idea of its relations to other subjects. The word SCIENCE is derived from the Latin *scio* (I know). From its derivation, therefore, we might expect a use broad enough to cover all knowledge. Its meaning has, however, usually been restricted so as to make it include only such knowledge as is systematically arranged, in accordance with discernible laws. Science, therefore, has to do with two great classes of facts, phenomena, and laws; the *natural*, or those concerned with the created universe, and the *supernatural*.

NATURAL SCIENCE in this broad, but, we believe, correct, sense may be conveniently divided as follows:

1. Mathematical Science, dealing with quantity;
2. Physical Science, dealing with the objects and laws of the material universe;
3. Social Science, dealing with the laws which govern the intercourse of mankind;
4. Metaphysical Science, dealing with the facts and phenomena of mind.

Many branches of knowledge may include facts or phenomena related to two or more of these divisions; for example, Astronomy may with reason be classed either as a mathematical or as a physical science, while Psychology involves the study of both physical and metaphysical science.

PHYSICAL SCIENCE, again, may be divided as follows; namely: —

1. Chemistry, which treats of the atomic forces of matter;
2. Physics, which treats of the molecular forces of matter;
3. Mineralogy, which treats of the nature and form of masses of inorganic matter;
4. Geology, which treats of the history of the earth and the changes which it has undergone;
5. Astronomy, which treats of the heavenly bodies;
6. Biology, which treats of the living organisms past and present upon the earth.

In its primary meaning, *Biology* (Greek *βίος*, life, and λόγος, treatise) had to do with the forces and processes of life; but as these can only be studied in connection with the organisms in which they are manifested, the term has come to be used to include the study of living organisms. Biology seeks to reveal the circumstances under which, and the methods by which, the varied and mysterious phenomena of life manifest themselves.

As regards the objects studied, biology therefore includes *Botany*, the science of plants, and *Zoölogy*, the science of animals. As regards phenomena studied, it includes a variety of subordinate subjects, each of which may be taken as a science in itself. Among the more

important of these are *Anatomy*, or the dissection of an organism to ascertain its component parts; *Morphology*, or the study of form and structure of organisms with reference to their relation to other organisms; *Physiology*, or the study of the functions of the various parts of the organism; *Embryology*, or the development of the organism from its germ; *Histology*, or the study of the microscopic structure of the tissues of which complex organisms are made up; besides many others which it is not worth while to enumerate here.

It is the purpose of the following lessons to aid the student in investigating these phenomena at first hand, giving such suggestions only as are likely to make the process as fruitful as possible, and yet leave the student the pleasure of discovering the facts to as great an extent as is consistent with economy of time and labor. To the serious student the following suggestions will be helpful: —

1. Search carefully and patiently for all the facts you can possibly discover.
2. Seek to make the facts interpret one another, and lead to some new knowledge of the object.
3. Make careful outline drawings, at least, of every organism you study.
4. Mark all drawings, to indicate how many times they are magnified or reduced, if they are not of the natural size of the object.
5. Carefully describe every part of each drawing, using symbols, with notes to correspond at the bottom or margin of the page.

CHAPTER I.

PROTOPLASM.

THE difference between lifeless and living bodies is so apparent that it is familiar to every one, but the phenomena which we designate by the term *life* are so perplexing that it is impossible at the present stage of scientific knowledge to explain them. They are, however, manifested only by a substance called *protoplasm* (πρῶτος, first, πλάσμα, form).

In its simplest form, this is a transparent, granular, and somewhat viscid fluid. Under a microscope of high magnifying power, the granules seem to be minute bodies which are less transparent than the viscid mass in which they are contained. Each mass of living protoplasm also contains one or more areas of a somewhat denser and more refractive substance, which is called the *nucleus*. It is also found that the best microscopes reveal minute fibres running through the protoplasm of the nucleus, giving it a considerably complex structure. There is generally discernible within this nucleus one or more very minute dots. Each of these is called a *nucleolus*. In some cases, however, this cannot be seen; while in still others it can be seen only with microscopes of an extremely high magnifying power, or by the aid of staining-fluids.

Protoplasm is found in its simplest form only in the simplest organisms or in very freshly formed parts of more complex organisms. It is generally surrounded

by a thin covering or wall formed by the modification of the outer layer of the protoplasm. The nature of this covering differs greatly in different organisms. The protoplasm thus surrounded constitutes what is called a *cell*, and the covering is called the *cell-wall*. In a few of the lower organisms the protoplasm is naked; *i. e.*, without any such cell-wall, *e. g.*, in the slime moulds which are sometimes formed upon decaying wood.

Most of the lower forms of both plant and animal organisms are composed of a single cell, while in the higher forms the cells are united in masses of greater and still greater numbers as the organism increases in size and complexity. All the essential processes of a living organism, however, are manifested by the single cell, and it is believed that the life of the most complex organisms consists in the united life of the individual cells of which the organism is composed.

PROPERTIES. — Living protoplasm manifests four characteristics which are called *essential properties;* viz., *Nutritility*, *Reproductility*, *Motility*, and *Sensatility*. Nutritility is that property by reason of which living protoplasm is able to absorb certain extraneous substances and transform them into protoplasm. This is called assimilation. A mass of living protoplasm is capable of dividing into two, and each of these again into two, and so onward. This power is called reproductility. Motility is that power by reason of which living protoplasm is capable of changing its form by internal currents of the protoplasm. Sensatility is that property by reason of which living protoplasm is stimulated into increased activity, or has its activity modified by external objects or forces.

In consequence of these properties of protoplasm, living organisms exhibit corresponding functions which clearly distinguish them from inorganic bodies. Inorganic bodies increase in size by the addition to their surfaces by accretion of molecules already similar to those of which the body is composed. On the other hand, the protoplasm of organic bodies possesses the power of taking to itself certain kinds of extraneous matter, and, by a process called assimilation, transforming it into protoplasm. This process is the basis of the growth of the organism as well as the source of supply to provide for the waste which is occasioned by the various forms of energy which the organism manifests. This process is nutrition, and is the most important of the vital processes, since it is the one upon which the others must depend.

Inorganic bodies, again, are not capable of multiplying themselves, while organic bodies, on the other hand, are capable of producing other organisms like themselves, so that while individuals are constantly perishing, each species is continued. This function seems in many of its aspects closely to resemble the former, while in other respects it is much more complex. The growth of the more complex organisms is due to the multiplication of individual cells, and the enormous multiplication of minute organisms is due to the same process.

Living protoplasm frequently shows streams of motion within its own mass, which are due to a power manifestly inherent in the protoplasm. Agencies which are external to the protoplasm, while they often modify this motion, are not sufficient to cause it. A slight increase of temperature will often increase the activity

of this motion; but an increase beyond a certain limit causes coagulation, or hardening, of the protoplasm, and the cessation of all manifestations of life. This property of protoplasm is motility. The power of contraction is also a modification of motility, and is the basis of motion.

Most forms of protoplasm exhibit a susceptibility to the influence of external agencies. The effect of varying temperature upon the motility of protoplasm, already referred to, is an illustration of this. When the protoplasm of an amœba comes in contact with food, the movements of the protoplasm seem to be modified by contact with the object, for the protoplasm soon flows around it and encloses it, this process seeming to be dependent upon the sensatility of the protoplasm. In the higher organisms this property is especially delegated to certain modifications of protoplasm called nerve-cells, but is not different in essential characters from that shown in the simplest forms of protoplasm. In plants, where no nerves exist, the property is often manifested to a remarkable degree. This property gives rise to sensation.

COMPOSITION. — Protoplasm is composed of carbon, hydrogen, oxygen, nitrogen, and sulphur in nearly constant proportions, together with the frequent presence of small quantities of calcium, magnesium, iron, phosphorus, sodium, potassium, silicon, chlorin, and some others. Even if we assume that the first five elements named are the essential constituents of protoplasm, we are still in doubt regarding the chemical formula of protoplasm. Various attempts have been made to reduce the results of numerous analyses to some definite formulæ, but thus far they have been fruitless. The

... elements are however present in nearly the follow-
ing proportions: C. 53; H. 7; N. 16; O. 22; S. 1.

MODIFICATIONS. — ... comparatively simple
... modifications of
... form above
... may be said to
... of protoplasm.
... well-determined com-
... itself, are not
... composition.
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... must be
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... which differ
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... Starch,
... are examples

... substances
... composed
... consequence

of a less quantity of oxygen, are more combustible than the carbohydrates.

While protoplasm has the power to produce from its own substance these various compounds, it has also the power to use them for its own nutrition. Thus, both plants and animals store up material in times of food abundance which may be utilized for nourishment at some future time when the supply of food is too small.

LABORATORY WORK.

For the study of protoplasm the hairs from the stamens of Tradescantia are best. If these cannot be obtained, fresh unbroken hairs from the tender portions of the common Nettle are excellent, and can be obtained late in the summer, when the Tradescantia is not in blossom. Filaments of Nitella may also be used to good advantage. In either case a single cell (in case of the nettle the terminal cell of the stinging hairs) should be examined. Place the object upon a clean glass slide in a drop of water, and cover it with a thin cover-glass, taking care to sop up the surplus water with a piece of blotting-paper. Examine first with a power of 40 to 50 diameters (× 40 or 50), and afterward with a power of × 200 or 300. In using the high power, first focus for the upper surface of the cell, and then slowly turn the fine adjustment until the central part of the cell is in clear view. Pursue the following directions: —

A. Observe and make a drawing to represent the following points: —

1. The *wall* of perceptible thickness which bounds the individual cell and encloses the protoplasm.

2. The granular *protoplasm* which partly fills the space within this cell-wall, lying unevenly distributed around the margin of the cell, and frequently with one or more streams running diagonally across the cell. Observe the motion of the granules in some particular stream, and look for a stream in some other portion of the cell in an opposite direction, forming a counter current.
3. A circular spot slightly more transparent, but denser than the rest of the protoplasm, the *nucleus*. Observe the arrangement of the main mass of protoplasm, and the direction of the streams with reference to the nucleus. In the nettle-hair this nucleus is usually at the base of the cell, and obscured by the other cells which surround it.
4. A minute dot, the *nucleolus*, may be found within the nucleus with a good lens of high power, though it is not usually seen with a low power objective.
5. The irregular spaces between the streams of protoplasm, the so-called *vacuoles*, filled with a clear fluid, the *cell-sap*.

B. Heat a piece of metal or a coin, and place it upon the glass slide (which should be supported upon two pieces of blotting-paper) near the cover-glass; or, still better, use a metal strip of the size of the glass slide, with a hole in the centre, and a long projecting arm under which a flame can be placed.

1. As the slide becomes warm, observe the effect upon the protoplasm.
2. When the slide becomes hot, note again.

3. Letting the slide cool, notice if the reverse effect is produced.
4. Watch for further behavior of the protoplasm for a short time.
5. What are the effects of heat upon living protoplasm?

C. Place the object on a very cold slide, or in ice-water for a few minutes, and quickly transfer to the slide.

1. How does the protoplasm behave?
2. After it has become somewhat warm, observe again. Is there any change?
3. Try the effect of freezing the object, if convenient.
4. What effect does cold have upon protoplasm?

D. Place a filament of Nitella or Chara upon a glass slide, and with a needle or other hard instrument press the protoplasm from the filament, and examine it in water, with a high power.

1. Note the appearance of the protoplasm in this condition.
2. Observe its behavior towards water.
3. Place a small drop of magenta solution at the edge of the cover-glass, and allow it to run under the cover. Note the effect upon the protoplasm, and upon other objects around it, such as particles of dust, etc.
4. In the same manner, stain a fresh mass of protoplasm with safranin, and examine it for the nucleus which may have been pushed out of the cell with the protoplasm. How is it affected by the stain?

CHAPTER II.

THE PROTEUS ANIMALCULE (*Amœba proteus*).

AMŒBA may be obtained either from the sediment at the bottom of ponds or pools of fresh water, or raised in infusions of hay. If a mass of the green plants generally known as pond-scum be left to stand for several days in a small quantity of water in a warm room, amœbæ will almost invariably appear in abundance. After bacteria have multiplied in great numbers in infusions of hay, amœbæ are almost sure to make their appearance. Rarely all the usual means will fail to secure them. In such a case recourse must be had to the text-books of zoölogy, or, still better, to Leidy's "Rhizopods of the United States." Having material supposed to contain amœba, put a drop on the slide and cover with thin glass.

MORPHOLOGY. — Examine with a low power especially the edges of each mass of debris for minute specks of clear protoplasm of irregular form. Having found such an object, use the high power to observe the following characters: —

1. The irregular and constantly changing form of the body.
   a. The blunt processes (*pseudopodia*) which are pushed out from the main mass of the animal.
   b. The greater clearness of the pseudopodia.

2. Structure of the body.
   a. The external, very delicate layer of protoplasm on the surface of the body, the *ectosarc.*
   b. The protoplasm enclosed by this ectosarc, and more dense than it, the *endosarc*, in which the food-particles are found. These layers are only feebly distinguished.
   c. A granular, grayish spot, the *nucleus*, usually of an oval form in the endosarc. More than one nucleus is sometimes present.
   d. A clearer spot, of a pinkish shade, in the endosarc, which disappears at nearly regular intervals, and reappears as suddenly, the so-called *pulsating vacuole, contractile vesicle.*
   e. Masses of food, such as diatoms, desmids, etc., which the amœba has taken into its protoplasm.

PHYSIOLOGY. — I. *Nutrition.*

1. Watch the amœba as it comes in contact with some particle of organic matter and engulfs it.
2. After the digestible portions of the food have been used, the remainder is dropped in the motion of the amœba.
3. Watch its behavior when it comes in contact with inorganic particles, as grains of sand, etc., if any are present. Look also in the body to see if it contains any such particles.

II. *Reproduction.* — Amœba multiplies in two quite dissimilar ways, —

1. *By Fission.* — An individual amœba may be seen to divide into two new individuals. This is generally preceded by the division of the nucleus into two. This may sometimes be seen

to take place while under the microscope, but is not of sufficiently frequent occurrence to be often observed, and yet amœba multiplies with great rapidity when it has an abundant supply of food and other favorable conditions of temperature and moisture.

2. Certain organisms nearly allied to amœba have been observed to assume a spherical form, develop a thickened wall, and remain quiet for a time. This inactive state lasts until favorable conditions return, when the protoplasm either breaks up into a large number of small bodies, called *swarm spores*, each of which is the germ of a new amœba, or else it escapes from its cyst and begins its active life again. It is probably from these spores, which are so minute as to float in the air, that the amœba originates in such large numbers in infusions of vegetable matter that are left open to the air.

3. *By Conjugation.*—Two amœbas have also been seen to fuse together and form one mass, which then goes through the ordinary process of fission described above. This is probably a simple form of *sexual reproduction*, consisting of the rejuvenation of cells after depletion from repeated generations of fission. There is, however, no differentiation of the reproductive cells.

III. *Motion.*—Notice the protrusion of a pseudopodium, and watch the mass of protoplasm which contains the nucleus and contractile vesicle follow it. In this way it will often move out of the field of the microscope in a short time.

IV. *Sensation.* — Find amœbas which are in active motion, and perform the following experiments upon them: —

1. Gently warm the slide with a heated iron, and note the effect upon the movements of the amœba.
2. Increase the heat, if practicable, until motion ceases, and the animal is dead.
3. A gentle electric shock produces temporary paralysis; a stronger one, death.
4. If an amœba be allowed only mineral food, it will not live. It requires food obtained from other living organisms. It seems also to be able to select food upon which it is able to subsist.
5. Try the effect of various poisons, — *e. g.*, mercuric chloride, picric acid, alcohol, — by running a drop of the solution under the cover-glass, and watching the behavior of the amœba as the poison reaches it.
6. If other rhizopods are obtainable, compare them with amœba. Leidy's work, as well as the works on general zoology, will suggest interesting forms for comparison.

CHAPTER III.

THE YEAST-PLANT (*Saccharomyces cerevisiæ*).

THE yeast of the market consists of a mass of cells of a microscopic unicellular plant, usually with a considerable quantity of starch-grains mixed therewith. When this is put into any substance that will afford nutriment for the growth of the plant, it multiplies very rapidly.

LABORATORY WORK.

MORPHOLOGY. — Put some yeast in water, and after it has become thoroughly mixed with the water put a drop of the liquid upon a glass slide, cover with the thin glass, and examine it first with a low power, and afterwards with the high power of the microscope. Determine the following points: —

1. Of what does the mass seem to be composed?
2. Notice the two kinds of particles most clearly seen, and compare them. The larger are *starch-grains*, and the smaller are *yeast-plants*.
3. Measure the size of each sort with the stage and eyepiece micrometers.
4. Observe the structure of the yeast-cells, and compare them with the starch-grains. The fine adjustment of the microscope should be freely used, while examining the particles, to be sure that not only the different cells may be compared, but the different portions of the same

cell may be clearly discerned. Make out the following; viz.: —

a. The thin *wall* which makes the boundary of each cell. This wall consists of a substance called *cellulose.* Compare with the starch-grain, in which there is no cell-wall.

b. The enclosed *protoplasm* and its peculiar characteristic appearance. Compare with the starch in this respect.

c. The transparent circular area in the centre of many of the cells, which to most eyes has a very faint pinkish tint, so that it seems at the same time clearer and darker than the granular protoplasm that surrounds it. This is the *vacuole*, and consists of a fluid not yet mixed with the protoplasm, called the cell-sap. Cells that have not been supplied with nourishment are more often without this vacuole. How does this compare with the vacuoles of the nettle hair?

REPRODUCTION. — Several hours before it is wanted for study, put some yeast in Pasteur's solution or a solution of sugar. Observe carefully the appearance of the fluid as showing the amount of yeast when it is first put in the solution. Set it in a warm place, and let it stand until it is needed for study.

1. Observe the changed appearance of the fluid. Examine with the microscope, and compare the abundance of yeast-cells now and at the previous examination.

2. Find cells in various stages of budding. In some the bud has just begun to form, in others it has nearly reached the size of the parent bud.

Occasionally there will be a bud at each end of the parent cell. After a time these break off and form new plants. This method of reproduction is called *gemmation*.

BEHAVIOR WITH REAGENTS. — In using any reagent, great care must be used to avoid getting the solution on the top of the cover-glass, and so bringing it in contact with the objective. With a small glass rod put a drop of the reagent at the edge of the cover-glass, and allow it to run under, thus gradually reaching the substance which is being examined. If it does not flow under fast enough, place a bit of blotting-paper at the opposite side of the cover, and draw out some of the liquid, and the reagent will take its place.

1. Put a drop of magenta solution under the cover, and watch the effect upon various objects in the field, observing which takes the stain most readily.
   a. The particles of dirt that happen to be in the field.
   b. The broken or dead cells of yeast.
   c. The starch-grains.
   d. The fresh and growing yeast-cells. How are the different parts, the cell-wall, the protoplasm, and the vacuole, affected?
2. Stain a fresh drop of the yeast with iodine solution, and observe the results.
   a. The starch-grains and yeast-cells take a very different stain. This is a valuable test for the presence of starch.
   b. How are the different parts of the yeast-cell affected by the stain?

3. Treat another fresh drop of the yeast with potash solution, and observe the results.
   a. The cell-wall is swollen by the potash.
   b. The protoplasm is destroyed.
4. How does the yeast-cell show the characteristic cell-structure which the starch-grain does not show?

PHYSIOLOGY.

1. Prepare test-tubes as follows, filling the tubes one-third or one-half full of the solution, and put a single drop of yeast in each: —
   a. Distilled water.
   b. Ten per cent solution of sugar.
   c. Pasteur's solution without sugar.
   d. Pasteur's solution with sugar.
   e. Same as *d.*
   f. Same as *d.*
   g. Same as *d.*
   h. Same as *d.*

Leave *a*, *b*, *c*, and *d* in a warm place for a few hours. Heat *e* to boiling, and put with *a*, *b*, *c*, and *d*. Put *f* in a dark but warm place. Put *g* in the direct sunlight. Put *h* in a cold place. After eight to ten hours examine the tubes, and make careful notes of the appearance of each. Examine the contents of each under the microscope, and make notes of the result. By comparison of these, what kind of food and what conditions do you conclude are necessary for the active growth of the yeast? In what cases is gas given off during the growth of the yeast?

2. Into a small flask one-half full of Pasteur's solution, with sugar, put a considerable quantity of yeast.

Fit the mouth of the flask with a cork into which is inserted a tube bent twice at right angles, so that the inner end will come just through the cork, and the outer end will come a few centimeters higher than the bottom of the flask. When bubbles of gas are freely given off, test it as follows: —

a. Insert the free end of the tube into a small open-mouthed bottle. After a time, insert a small burning splinter into the bottle, and note the results.

b. Dip the free end of the tube beneath the surface of a small amount of lime-water, and let the gas bubble through the water. Carbonate of lime is precipitated. The precipitate formed in the lime-water may be tested to prove that carbon-dioxide is given off when the yeast is growing actively in the presence of sugar or starch. It is this gas which causes the dough to swell up in the rising of bread.

Carefully made drawings should show all the points named above, as far as possible, and a careful description, covering all points, should be written.

CHAPTER IV.

GREEN CELLS (*Protococcus viridis*).

THE bark of many of our trees, especially the maple and elm, is usually more or less covered with a green and somewhat mealy mass which under the microscope is seen to consist of minute colorless cells of a lichen, mingled with numerous globular green cells of a plant called *Protococcus viridis*. The life history of the groups of plants similar to this is not known, and it may be but a single stage of some other plant. For our present purpose we may call it as above, and use it for purposes of study.

MORPHOLOGY. — Scrape off a small quantity of the greenish mass and place it in water upon the slide. Examine it carefully with a simple lens, and notice the appearance. Cover it with the thin glass circle, and place a small piece of blotting-paper upon the cover-glass, and with the finger gently press the blotting-paper and give a rubbing motion. This will separate the mass so that it can be better examined. Observe the green protococcus cells mixed with the transparent and generally broken cells of lichen. Note the following: —

1. The single cells of varying size. In each observe:
   a. The cell-wall.
   b. The protoplasm which it encloses, filled with a green coloring matter called *chlorophyl.*

c. The nucleus clearly seen in most of the cells.

d. The form and size of the cells. Measure.

2. In a mass that has been gently rubbed there will be seen cells that seem to be united loosely in groups. Determine —

a. The usual number of cells in a group.

b. Whether there is any covering for the group of cells.

3. Observe the effect of reagents.

a. Stain with safranin to show more clearly, if need be, the presence of the nucleus.

b. Treat with iodine for the presence of starch-grains.

c. Treat with alcohol, and note its effect upon the chlorophyl.

d. Treat with potash to dissolve the protoplasm.

REPRODUCTION. — In a mass that has been exposed to sunlight and moisture for a number of hours look for the reproduction which can usually be seen in a few cells.

1. The protoplasm of each cell divides into two masses, and each of these into two more, and so on, each portion becoming a separate plant. This is called *fission*.

a. Look for various stages of division.

b. Determine at what stage in successive division of the cells they separate.

c. Compare these results with *A.* 2.

2. In certain cells found in fresh water apparently similar to them, a stage occurs in which the protoplasm bursts its cell-wall and comes forth in a round mass, a clear area appears on one side

slightly protruding, and from this two long whip-like filaments, called *cilia*, make their appearance, and by a rapid vibratory movement send the organism spinning through the water with a rolling motion. This is called the motile, or zoöspore, stage. After a time the cilia cease to move, become absorbed, the protoplasm secretes a cell-wall, and the organism enters a state of rest. Later it begins to divide, and goes through a series of generations such as above described. This stage is best seen in the cells of *Gleocapsa*, that are found in the edge of quiet streams. (I have not been able to find it in those from the bark of trees.) Having found a zoöspore, observe the following: —

a. The absence of the cell-wall.

b. The form of the green protoplasm.

c. The clear uncolored space on one side.

d. The two cilia at this point.

e. The rapid motion of the cilia.

f. The locomotion of the mass produced by this motion of the cilia.

To distinguish all these it may be necessary to remove the water slowly by blotting-paper until the cover-glass somewhat retards the motion.

PHYSIOLOGY. — A considerable quantity of protococcus should be placed in two watch-glasses in clear rain-water, and covered with another watch-glass.

1. Let one of these stand in the clear sunlight for several hours, after which they may be examined in regard to the following points: —

a. Do the cells seem to have multiplied in the water?

b. Are they in a healthful condition?

2. Put the other in a dark place for an equal time; afterwards examine and compare with 1 *a* and *b*.
3. Plants having chlorophyl have the power of taking up carbon dioxide and decomposing it in the presence of sunlight, setting free thereby oxygen, and using up the carbon in the manufacture of protoplasm.

NOTE. — Various other unicellular green plants may be found which will serve instead of protococcus or as a supplemental study. It is well to compare several slightly different species. For determining the species, the student is referred to Wood's "Freshwater Algæ," and Bessey's "Botany."

CHAPTER V.

SOLE ANIMALCULE (*Paramæcium caudatum*).

PARAMÆCIUM may be taken as an example of a very large group of single-celled and free-moving animalcules which differ from amœba in so many points that it seems worth while to make one of them a subject of special study. From the great abundance in which these minute animals appear in infusions of vegetable matter they have been named *infusoria*. They may be found in great abundance in the infusions from which amœbæ have been obtained, usually a few days later, and are generally abundant in any material in which amœba has been found.

Many species of this genus (paramæcium) and others may appear, either of which will serve the purpose of study. In a drop of water supposed to contain paramæcia, look with the low power for minute bodies moving rapidly about in every direction. In order to keep any one of these in the field of the microscope long enough to get any correct conception of its structure, it will be best to select one, if possible, that is shut in a narrow space by débris. If this is not possible, very slowly and carefully absorb the surplus fluid by the use of blotting-paper until the film is so thin as to allow the animal only little motion. Much care will be needed that the animal be not crushed by the weight of the cover-glass, and it should be able to move about somewhat to give better opportunity to study it. Now examine it with regard to the following particulars: —

MORPHOLOGY. — Compare carefully with amœba.

I. *Form and external appearance.*

1. It does not change its form like amœba. If its form is changed by pushing through a narrow passage, it is at once restored when it emerges.
2. One end of body seems inclined to move foremost though the ends differ very little; hence a tendency to a *fore-and-aft polarity.*
3. There are no pseudopodia, but in place of them the body is more or less covered with minute, hair-like projections which move back and forth like paddles. These are called *cilia.* They are generally larger in some portions of the body than others, especially near the anterior end.
4. Near the anterior end is a depression upon one side, in which may be seen, as the body turns over, an opening which is the *mouth.* This opening is usually surrounded by the longer cilia already mentioned.
5. This opening leads to a funnel-shaped tube, the œsophagus, which leads to the interior of the body, and ends openly in the soft protoplasm.

II. *Structure.* — In this connection notice: —

1. The distinction between the *ectosarc,* or outer layer, and the *endosarc,* or inner mass of protoplasm, is more readily discernible than in amœba.
2. The nucleus, its location and form.
3. One or more pulsating vacuoles are present in the endosarc.
4. There are usually several masses of food in the endosarc which have entered by the mouth and

œsophagus to the central mass of the endosarc. These masses may be enclosed by a fluid more clear than the protoplasm, and called a *food vacuole.* This vacuole may be caused by the water taken in with the particles of food.

5. These masses finally collect in regions near the end opposite the mouth after the nutritious portions have been absorbed, and escape by the rupture of the cuticular layer, thus forming a temporary but uniformly located *anus,* which closes immediately after the discharge of the undigested food mass.

PHYSIOLOGY. — I. *Nutrition.*

1. Watch the motion of the cilia around the mouth. By means of this motion a vortical current is produced over the mouth, and thus particles of food, as minute plants and smaller animals, are brought to the mouth.
2. The endoplasm of the animal has the power to digest the nutritious portions of the food thus taken and to assimilate it.
3. Only particles of organic matter are thus taken into the protoplasm.

II. *Reproduction.*

1. Paramæcium may be frequently found in a condition of partial division. If such a specimen be watched for some length of time, the division will be completed, and each part become a perfect paramæcium. This division begins with the division of the nucleus, after which the portions containing the two nuclei slowly separate. This method of multiplication is called *fission,*

and by it many of the lower forms of life increase with great rapidity.

2. At certain periods the power of paramæcium to reproduce by fission seems to be exhausted. Here another process comes in to replenish the energy of the organism. Two animals, coming in contact with one another, gradually fuse together. The organism which results from this fusion generally loses its cilia, assumes a spherical form, and becomes enclosed in a thickened membrane, and remains thus inactive for a time. After this period of inactivity the protoplasm breaks up into a number of smaller bodies, which escape, and become individuals like the original. Here again is an example of the process of conjugation, still without any differentiation of individuals.

III. *Motion.* — Here observe the following points: —

1. The distribution of the cilia, and size in the different portions. Can this have anything to do with the direction in which the organism moves?
2. The form of the cilia. This can be seen only when the cilia are vibrating very slowly, as when the paramæcium is losing its vitality, or is feeling the effect of some poison. Why does the back-and-forward motion of the cilia give motion in one direction to the organism?

IV. *Sensation.* — Notice the behavior of the animal as it comes in contact with other objects. Is this any indication of sensibility? Experiment upon it in a manner similar to amœba. Is there any indication of localized sensibility?

CHAPTER VI.

THE BELL ANIMALCULE (*Vorticella nebulifera*).

THIS or some other species of Vorticella, or Epistylis, to all of which the name bell animalcule is applied, may usually be found in small numbers attached to minute aquatic plants in any of our quiet ponds or pools of fresh water.

If the lichen and protococcus used in Chapter V. be left to stand in water for a few days in a warm room and frequently examined, Vorticellæ will be pretty likely to be found in considerable numbers. Having obtained the specimens, the following scheme will aid in learning their structure: —

MORPHOLOGY. — Take a bit of the sediment from the bottom of the vessel, and with a low power search for animalcules. After finding them, they may be examined with a higher power for the following: —

I. *External Appearance.* — Note the form of the body.

1. The bell-shaped body supported in an inverted position upon a slender stalk.
2. The slightly thickened and everted rim, the *peristome.*
3. The circle of cilia upon this rim.
4. Occasionally, one is seen with another circle of cilia near the point of attachment to the stem.

This soon separates from the stalk and becomes free-moving.

5. On one side of the flattened surface of the bell is an opening which is rather more thickly beset with cilia. This is the *oral opening*, or mouth.
6. The mouth is followed by a short tube which can be seen through the transparent protoplasm of the body leading to the centre of the protoplasm mass. This is the *œsophagus*.

II. *Structure.* — Note the following: —

1. The delicate outer covering, the *cuticle*, almost invisible, which covers the whole body.
2. The thicker and rather transparent outer layer of the protoplasm, the *ectosarc*.
3. The inner mass, occupying the centre of the body, the *endosarc*.
4. The somewhat elongated and curved nucleus of the cell of which the animalcule is composed. This can be better seen by running a drop of acetic acid under the cover-glass after the other points have been made out.
5. One or more round, transparent bodies which alternately disappear and reappear at short intervals, as if by the contraction of the surrounding protoplasm, the *pulsating vacuole*, of a clear, pinkish shade.
6. Certain other bodies in the protoplasm of the endosarc, of various shape and size. These are particles of food which have been swallowed by the animalcule.

PHYSIOLOGY. — As in the previous chapters, study, —

I. *Nutrition.* Under this subject, note: —

1. The motion of the cilia around the mouth, and watch for the ingestion of particles of food.
2. The food, like that of amœba and paramæcium, is enclosed in, and therefore in contact with, the protoplasm. Whatever portions of the ingested object are serviceable for food are directly absorbed by the surrounding protoplasm. Whether there is any process of digestion, it is difficult to say. Most of the food of these lower forms is so simple that little digestion is necessary.
3. The unused portions of the food are rejected in the same manner as in amœba and paramæcium.
4. After the absorption of the nutritive portion of the food, or at the same time, a process of transforming it into the peculiar form of protoplasm required must take place. This process is called *assimilation.*

II. *Reproduction.* — Like the other forms studied, vorticella has two methods of reproduction, —

1. *Fission,* or asexual reproduction. This consists of the following stages: —
   - *a.* The body becomes permanently contracted and slightly changed in form. The protoplasm seems to be more transparent, and the nucleus more conspicuous.
   - *b.* The nucleus divides into two, and this is followed by the division of the body into two distinct masses of a rounded shape.

c. Each of these develops a peristome and other structures, thus becoming a perfect vorticella.

d. Sometimes this division extends down the stalk, and each becomes a separate stalked individual; and by the repetition of this, a group of individuals is formed.

e. Sometimes, however, one of the individuals is smaller than the other, develops a circle of cilia near its lower end, and becomes detached from the stalk and moves off by means of its cilia, thus leading a free-moving life.

2. *Conjugation.*— *a.* A free-moving individual, such as the one just described, comes in contact with the body of a fixed individual by its aboral end, fuses with it, and the two form one mass, which at once assumes a somewhat spherical form, secretes a thick covering, or, as it is stated, becomes *encysted*, and remains inactive for a considerable length of time.

b. After this encysted stage, or possibly sometimes without becoming encysted, it assumes the ordinary form, and the process of life goes on as before, including the process of fission. This method of reproduction shows the first traces of differentiation of the pairing individuals, and indicates a step towards the sexual relations of the higher animals.

III. *Motion.*—The form of the animalcule is defined and permanent, save as the contraction of the peristome modifies it temporarily. The protoplasm is confined in a definite form by the stiffening of the ectosarc, so that the motility of the protoplasm is somewhat localized.

1. The cilia upon the peristome and disk are capable of a very vigorous vibrating motion, which is undoubtedly a modification of the general motility of the protoplasm. These are permanent organs of motion, serving to move the water to the fixed form, and to propel the free-moving form.
2. The peristome is specially possessed of the power of contraction, which indicates a very decided localizing of the power of motility.
3. The sudden contraction of the stem also indicates a special localizing of the power of contraction. Indeed, there can be seen some of the contractile fibres which make this contraction possible in the stalk of the animalcule, and may be considered the beginnings of *muscular fibres.*

IV. *Sensation.* — Observe the effect of a gentle tap on the glass slide. The stem will be likely to contract suddenly, showing the sensibility of the protoplasm to external disturbances.

Compare other stalked infusoria with vorticella, if they are to be had, and note the points in which they differ from it.

RÉSUMÉ TO CHAPTERS II. TO VI.

Let the student carefully compare his notes on the organisms thus far studied, and see in what points they agree, and in what others they differ, noting especially the following: —

1. The number of cells in each organism.
2. The structure of the cell.
3. The kind of food needed to support the life of the organism.

CHAPTER VII.

PLANTS AND ANIMALS DISTINGUISHED.

THE organisms thus far studied agree in this regard, that each organism consists of a single mass of protoplasm, generally surrounded by a more or less distinct envelope, and possessing the essential nucleus. They may therefore be called *unicellular organisms.* Yeast and Protococcus, however, are able to subsist upon mineral food, while Amœba, Paramœcum, and Vorticella require food which has already been prepared by some other organism. This is the essential difference between plants and animals, and is the only distinction which does not find some exception. The higher plants differ widely from the higher animals, but it is among the lower forms that the difficulty of distinguishing them is greatest. The presence of cellulose in the cell-wall is a universal character of plants, but it is possessed by some animals. Starch and sugar are characteristic products of plants, but are not found exclusively in plants. Green chlorophyl is, generally speaking, a plant product, but parasitic and saprophytic plants are usually without it, and a few animals possess it. The radiate arrangement of parts generally prevails in plants; as we shall see, it is also characteristic of several groups of animals. Most plants are fixed, and most animals have free locomotion; but many animals are fixed, and some plants move very

rapidly and freely in water. Thus are we driven to the one essential distinction between plants and animals, namely, that plants are able to assimilate mineral food, while animals must have food which has been prepared by some living organism.

Of the four essential properties of protoplasm, and the functions growing out of them, something may be said. Of the power of nutrition and reproduction, plants are as highly possessed as animals. The power of motion is more fully developed in animals, and the power of sensation is much more perfectly developed in animals; though probably all plants move, and many plants are sensitive to external stimuli.

For convenience of study and comparison, it is necessary to classify plants and animals according to their similarities of structure, and for this purpose the following terminology is used. Every plant and animal which has been described has a binomial designation. Organisms which are practically alike are said to belong to the same *species*. Species which are similar, but not identical, are united in one *genus*. The genus and species names together constitute the scientific name of the organism. Thus *Amœba proteus* is a species of the genus Amœba, which consists of several other species. Similar genera are united into one *family*, similar families into one *order*, similar orders into one *class*, similar classes into one *branch*, and all branches of plants into the *vegetal kingdom* and all branches of animals into the *animal kingdom*. The arrangement, then, is as follows: —

Branch.
Class.
Order.
Family.
Genus.
Species.
Individual.

A mere sketch of the classes of the various branches may be of some aid to the student in his study. Such an outline is given after the various types studied.

The plants we have thus far studied are representatives of a group of plants distinguished as: —

Branch **PROTOPHYTA**: Plants consisting of a single cell, and multiplying with exceeding rapidity, either by fission or budding. They are mostly microscopic in size. In a few forms the cells are inclined to adhere in chains or short filaments.

Class **Schizomycetes**: Plants multiplying by transverse division. Mostly saprophytic; that is, living in infusions of organic matter, which they probably cause to break up into simpler chemical compounds. Many of them are germs of the most destructive diseases known. Here belong the various species of bacteriaceæ.

Class **Saccharomycetes**: Plants multiplying by budding, and forming important agents in the process of fermentation. Here belong the forms of yeast.

Class **Cyanophyceæ**: Plants multiplying by transverse division, the cells sometimes remaining attached loosely together, and containing green coloring-matter, chlorophyl, and often other coloring-matter in connection with the chlorophyl. Here belong the various forms of Protococcus, Chroöcoccus, and their allies, Gleocapsa, where the cells are

often grouped together in small clusters, the Nostocs, Oscillaria, and Rivularia.

The animals studied represent also the lowest group of the animal kingdom. These constitute the: —

BRANCH **PROTOZOA**: Animals consisting of a single cell of very simple structure and multiplying both by fission and conjugation.

Class **Mycetozoa**: Protozoa found in masses, with the protoplasm of the individual cells blending, so that the only traces of the individuals are the nuclei. These are slimy masses found on decaying wood and vegetable substances.

Class **Rhizopoda**: Protozoa with no external organs except pseudopodia. This includes Amœba and its allies the sun-animalcules, chalk animalcules, and flint animacules.

Class **Infusoria**: Protozoa with permanent vibratile cilia. This class includes the flagellate infusoria (with one or two long, whip-like cilia), the Paramœcium and bell animalcules and their allies.

Class **Gregarinida**: Parasitic protozoa, with elongated, worm-like bodies, found in the internal organs of higher animals.

CHAPTER VIII.

POND SCUM (*Spirogyra longata*).

THE silky, green threads which occur in great abundance in most of our stagnant pools may consist of one or more species of filamentous plants, of which some species of Spirogyra is almost sure to be one. If the mass of slippery threads be put in a flat, white porcelain dish the beautiful filaments of Spirogyra, with their spiral bands of chlorophyl, can be readily recognized with the aid of a good lens, and separated. Care must be taken not to break the filaments or crush them, as they would then be of no value for study. Place a filament in a coil upon the glass slide in a drop of water, cover with thin cover and examine first with a low and afterwards with a higher power, when the following characters may be distinguished: —

MORPHOLOGY. — I. *The form and structure of the filaments.* They are composed of numerous cells in a single row.

1. How are these cells arranged?
2. Note the form of the cells.
3. The union of the two end walls of two contiguous cells into one thickened wall.
4. In some species there is a curious folding-in of the end of the cell.

5. Note the form of end cell in a perfect filament.
6. Note the varying length of cell in different parts of the same filament.

II. *The contents of the cell.*

1. The green bands of protoplasm within the cells. They are called *chlorophyl bands.*
   - *a.* What is the coloring matter in this?
   - *b.* Note the edge of the bands in freshly growing specimens.
   - *c.* Follow a band for some distance, changing the focus so as to keep the portion you are examining in sharp focus. What does this show of the arrangement of the band?
   - *d.* Note the number of bands in each cell. If you count the number of times one band is crossed by others in a single half-turn and add one, you will have the number of bands.
   - *e.* Note how many complete turns each band makes in the length of one cell.
   - *f.* Note the minute bodies imbedded in these chlorophyl bands. They are known as *chlorophyl bodies.*
2. Examine a number of cells for a mass of clear and colorless protoplasm. It will generally be found near the centre of the cell, and will be in clear focus just after the upper turn of the band ceases to be in sharp focus, and just before the lower one becomes sharply defined. This is often obscured by the chlorophyl bands, especially when there are several crowded together.
   - *a.* There are usually several radiating streams of protoplasm extending to the wall of the cell.

b. These connect the central mass with a thin layer of protoplasm just within the cell-wall.

c. This central mass contains a distinct nucleus. In some species the mass which contains the nucleus consists of a bar of protoplasm extending across the cell.

PHYSIOLOGY. — I. *Nutrition.* Since each filament is composed of cells placed end to end in a single line, every cell is exposed to the surrounding water and is liable to take nutriment therefrom for itself.

1. As the protoplasm is surrounded by a cell-wall, this nutriment must be absorbed through the wall by the process of osmosis.
2. Compare the diameter of different filaments and of different cells in the same filament.
3. Compare the length of the different cells in the same filament and in different filaments.
4. From these comparisons, in what direction do you infer that the increase of the size of the cell takes place?
5. When the cells have reached a certain size, the limit of which is quite variable, each cell divides into two. This process begins with the nucleus, which divides into two. This is followed by certain modifications of the form of the protoplasm, which becomes arranged with regard to the two nuclei, and later by the formation of a partition of cellulose between the two masses and across the cavity of the cell. In Spirogyra this process is said to occur only in the night, but it is quite possible to find cells which show by their length that they have been recently

formed in this manner. This process is manifestly identical with the process of asexual reproduction in Protococcus save that the cells do not separate.

II. *Reproduction.*

1. The union of individual cells of the Spirogyra filament is so feeble that long filaments not infrequently become divided by the gradual separation of two cells in the filament, thus forming two new plants. In such cases the end cells become rounded at the point of union.
2. Another and much more important method of reproduction is the process of *conjugation.* After a season of rapid growth, particularly in the spring, the masses of Spirogyra become a dirty-brown color. This will sometimes occur in aquariums that have been stocked late in the fall and allowed to grow rapidly in a warm room. Examination of the filaments at this stage will reveal pairs of filaments arranged parallel to one another, in which will be found projections from the cells of one filament reaching toward corresponding projections from the cells of the parallel filament, or perhaps even in contact with them. The protoplasm of these cells, becomes aggregated into an ellipsoidal mass, and that from one filament passes through the passage formed by the union of the two projections, and coalesces with the similar mass in the other filament. The whole then becomes dark-brown and secretes a thick wall, after which, being set free by the decay of the wall of the old filament, it falls to the bottom to

await favorable conditions for development. This mass is called a *zygospore* (*ζυ̃γον*, yoke). The cells which unite in this conjugation are similar in both size and appearance.

3. The germination of these zygospores consists of the swelling of the protoplasm until the outer wall bursts, when the mass assumes an elongated form, secretes a cell-wall, increases in length, divides into two cells, and each of these into others as they increase in size, until a long filament is formed.

III. *Motion.* Slight movements of the protoplasm within the cell-wall can sometimes be distinguished, but the contents of the cell is so deeply colored with chlorophyl that the movements are difficult to detect.

BEHAVIOR WITH REAGENTS. — Use fresh specimens in each case.

1. Stain with magenta to distinguish more clearly the cell-wall.
2. Put a mass of filaments into alcohol and observe that the alcohol is colored by the chlorophyl. Place one of the filaments under the microscope, and note: —
   a. The color of the chlorophyl bands.
   b. The form of the whole cell-contents.
   c. The position of the thin layer of protoplasm just beneath the cell-wall. What effect has the alcohol upon the protoplasm?
3. Run a solution of iodine under the thin glass which covers a fresh filament which has been exposed to sunlight, and observe the effect upon the contents of the cell. Do not stain too rapidly.

a. The outer edge of the chlorophyl body assumes a faint blue tint, — indicating what?

b. The central mass is of a denser nature and is called a *pyrenoid*.

c. The whole band will finally be stained brown.

IV. Run glycerine under the cover-glass slide.

a. The whole mass of protoplasm will become much contracted.

b. The central mass of protoplasm and the nucleus enclosed in it will usually be made more evident.

c. The nucleolus may sometimes be seen imbedded in the nucleus.

CHAPTER IX.

BLACK MOLD (*Mucor mucedo*).

VARIOUS forms of mold are much too common for ordinary convenience. Many of these are, however, interesting objects of study. For this purpose the common black mold, *Mucor mucedo*, or one of its relations of the genus Mucor, is perhaps most convenient. It may be found upon a great variety of decaying substances. It may be cultivated in a convenient form for study on the surface of some liquid, as decoction of horse-dung, free from opaque matter which would render its study inconvenient. For study of the ordinary processes of growth, the common blue mold, *Penicillium glaucum*, or gray mold, *Eurotium repens*, common on bread or preserved fruit, will serve equally well. The reproduction, both sexual and asexual, however, is very different from that of Mucor.

MORPHOLOGY. — I. Examine a mass of mold and it will be seen to consist of a very dense network of interlacing fibres called *hyphæ*, forming a mat upon the surface of the substance upon which it feeds. From this mat of fibres, which is called the *mycelium*, there will be found to rise numerous erect *hyphæ* bearing on their summits minute heads, from which a fine dust rises when they are disturbed. To study the plants, place a small piece of the mycelium upon a

glass slide, being careful to avoid disturbing the delicate erect hyphæ. Examine it with the lowest power of the compound microscope, and note the relation of the various parts of the plants.

II. Carefully separate a few of the filaments, and place them under a cover glass in a drop of alcohol. If water is used it will not readily flow around the filaments, but will entangle numerous bubbles of air which will greatly disturb the examination. Observe: —

1. The horizontal hyphæ which make up the mycelium.
   a. Are there any divisions into cells? If so, how frequently?
   b. Are the filaments simple or branched?
   c. What is the appearance of the cell-wall?
   d. How does the contents of the cell compare with that of Spirogyra?
2. The erect hyphæ. — *a.* Note their mode of branching from the hyphæ of the mycelium.
   b. Are they divided into cells?
3. The heads on the summit of these hyphæ. Look for various degrees of development, which can be found readily if the mould is in the right degree of advancement.
   a. Some with the end of the hypha slightly enlarged, and divided off from the rest, and its protoplasm somewhat more granular.
   b. Others with the end greatly enlarged and the transverse partition pushed upward in the centre so as to make it convex upward.
   c. Still others in which the protoplasm of the head is broken up into minute spherical bodies called *spores*.

d. Others again in which the outer wall of the head, which is here called the *sporangium*, is broken open and allows the spores to escape. This they do in the form of dust, as mentioned above.

e. In these burst sporangia the transverse portion which separates the sporangium from the lower portion of the hypha is usually pushed upward to a considerable degree and forms what has been called the *columella.*

PHYSIOLOGY. — I. *Nutrition.*

1. As only a portion of the filaments of the mold are in contact with the nourishing substance, it must follow that there is a division of labor. Those portions which receive nourishment by osmosis, as in the previous plant, must give up a portion of that nourishment to the remainder, and this is done by osmosis as in the former case.
2. Experiments prove that while mold naturally flourishes upon decaying organic matter, it can be cultivated upon certain inorganic solutions. For a description of certain of mold spores see "Bessey's Botany," page 240.

II. *Reproduction.*

1. One method of reproduction of Mucor is by means of the spores already described. When these spores fall upon a suitable medium they absorb nutriment and send out elongations, which form the filaments of the mycelium. The number of spores falling in any particular spot is usually so great as to form a very dense mycelium. From the filaments of this mycelium arise the erect

hyphæ which produce the sporangia, and a new crop of spores. The corresponding process in Penicillium or Eurotium differs in growth of the spores. The erect hyphæ become branched at the top, and each branch separates transversely into a number of spores. Such clusters of spores are called *conidia*. In Penicillium the conidia are in a bush-shaped cluster, and in Eurotium in a head.

2. The sexual reproduction of mucor is similar to that of Spirogyra. Two filaments send out Processes which unite and allow the protoplasm of the two to come together and form a *zygospore* as in Spirogyra.

A group of plants based upon the method of reproduction just studied in Spirogyra and Mucor is the following: —

BRANCH **ZYGOPHYTA**: Plants having, in addition to various methods of producing asexual spores, the habit of producing zygospores, from which a new series of generations is developed. This method of reproduction seems to be coördinate with the conjugation of the Protozoa, and like that to represent the sexual reproduction of the higher forms. In this branch are the following classes, namely: —

Class **Zoösporæ**, in which the asexual reproduction is by numerous spores, each possessed of two or more cilia and capable of very rapid motion. The sexual conjugation is often between these free-moving zoöspores. The plant's cells are only very loosely united, either in clusters as in Pandorina, or in flat masses like Hydrodictyon or Pedastrium.

Class **Conjugatæ**, in which the plants multiply rapidly by fission and either remain attached in filaments or become nearly separated at once. Many of them are of exquisite

form and marking, as the Desmids, or have marvellously constructed silicious shells, as the Diatoms. Others form filaments with the protoplasm arranged in the most beautiful patterns, as in Spirogyra and Zygnema. Others are saprophytic, as Mucor, Mesocarpus, and other allied molds in which there is no chlorophyl.

Another plant often found with Spirogyra, called Oedogonium, in which the green coloring-matter is distributed throughout the cell, differs in its reproduction in a very interesting way. The protoplasm of a much enlarged cell, called an *oögonium*, arranges itself in a rounded mass as in Spirogyra. This is called an *oösphere*. A small cell called the *antheridium*, which has been developed from its side or upon another filament sends out a small oval mass of protoplasm with cilia at one end. This is called a *spermatozoid*. The spermatozoid enters the oögonium by an opening at one end and unites with the oösphere which usually develops a hard covering and is called an *oöspore*. It remains for a time inactive, and then develops into a filamentous plant. A group of plants based upon a mode of reproduction like this is: —

Branch **OÖPHYTA**: Plants producing unlike sexual elements, oöspheres and spermatozoids, by the union of which an oöspore is produced. Of this branch the classes also vary much in form of the plant body.

Class **Volvocaceæ** has the plant cells arranged in a spherical mass, and is here made to include Volvox, the position of which is at present very poorly understood.

Class **Oedogoniaceæ** includes filamentous plants like Oedogonium, Pringsheimia, Androgynia, Bulbochæte, etc.

Class **Coeloblastiæ** includes the very simple Vaucheria, and a very large number of saprophytics, as Saprolegnia, which lives upon dead animals in water and sometimes attacks living animals, and parasites like Peronospora and Cystopus, which are very destructive to plants.

Class **Fucaceæ** has the plant body of large and sometimes of enormous size. This includes the larger sea-weeds, such as Fucus, Sargassum, Macrocystis, Laminaria, etc. In these the oögonia and antheridia are borne in sac-like depressions, called concepticles, of the surface of the plant body.

CHAPTER X.

A STONEWORT (*Chara fragilis*).

THE Stoneworts are green plants which live entirely under water, and may be found growing from the bottom of quiet ponds and sluggish streams. Several species of Chara or Nitella are found in the United States, either of which will serve for this study. Each plant consists of a main stem, with branches arranged in whorls along this main stem. These branches have still more minute branchlets upon them, at the junction of which with the branches may be found in summer the reproductive organs. These plants may be raised in aquariums, if wanted at a time when they cannot be obtained from the ponds; in this case it would be well to have preserved in alcohol specimens of the fruiting organs for class study.

MORPHOLOGY. — I. *Anatomy.* Put a plant in a shallow dish of clear water, and examine its parts. Note —

1. The cylindrical stem or axis of the plant, which is divided into internodes by the arrangement of the branches at the nodes.
2. The slender root-filaments growing from the base of the stem.
3. The whorls of branches arranged at intervals along the axis of the stem. These are often called leaves.

4. The branchlets at the nodes of the branches. These are by some writers called leaflets. Minute globular green cells are often found at the nodes, which are undeveloped branchlets.
5. The brown reproductive organs at the junction of the branches and branchlets, found only in mature plants.

II. *Microscopic Structure.* — Examine a portion of the plant under the low power of the microscope, noting:—

1. The structure of the stem. All the species of Nitella, and some of Chara, have only a single cell for each internode, while others have a large cylindrical cell in the centre, with a number of long and narrow cells arranged around it, forming a *cortical layer.*
2. The arrangement of chlorophyl bodies just within the cell-wall, in lines running obliquely lengthwise of the cell, forming a very open spiral. These are in an outer layer of firm protoplasm.
3. Notwithstanding the dense coloring of the protoplasm with chlorophyl, an inner mass of mobile protoplasm can be discovered by the motion of the granules in regular currents and counter-currents.
4. Within this mass of protoplasm is the nucleus, which will be most easily found in the younger cells, where the coloring is less dense.
5. The union of the cells which constitute the branches with the main stem.
6. The form of the branchlet cells, especially the thickened walls at the tips of the free ends.

PHYSIOLOGY. — The various functions which are characteristic of plant life, particularly of aquatic plants, are well illustrated in the life of the Stonewort.

I. *Nutrition.* — Observe a growing plant from day to day, measuring the length of the internodes and the number of the nodes. The following phenomena are apparent: —

1. The length of the internodes increases from day to day.
2. New cells are formed at the end of the stem, and branches where a growing bud is seen. These cells increase in size, and form new branches, as well as help to extend the length of the stem.
3. Multiplication of cells, therefore, in this case, instead of increasing the number of separate plants, as in Protococcus and other unicellular plants, results in the growth of the plant, as in Spirogyra, but in a still more specialized manner, since the new cells are formed at the end of the stem and branches.
4. The material which makes growth and cell-multiplication possible is received —
   - *a.* From the water, by direct absorption through the walls of the cells, except in those cells which form the axis of the stem and are surrounded by the cells of the cortical layer, which must of course receive their food from the cells by which they are surrounded.
   - *b.* Some nourishment is absorbed from the earth by means of the simple rootlets by which the plant is anchored to the bottom of the pond or stream in which it grows.

II. *Reproduction.* — Asexual reproduction, such as we have seen in some of the lower plants, does not occur in the Stoneworts. Sexual reproduction is more complex. In mature plants of Stonewort there may be seen, at the junction of the branchlets with the branches, the reproductive organs. These are of two sorts.

1. In the axil of a branchlet will be found a brownish body, the *carpogonium*. This consists of: —
   - *a.* An outer layer of five cells, arranged in a spiral manner and forming a capsule, on the top of which is
   - *b.* A tuft of terminal cells.
   - *c.* A large cell enclosed by the outer layer, and forming the germ-cell, or *carposphere*.
2. At the side of the axil, or below it, may be seen another more nearly spherical body, the *antheridium*, which, like the carpogonium, consists of: —
   - *a.* An outer layer of eight flattened cells of a triangular form. From the inner surface of each of these cells projects a cylindrical cell called the *manubrium*, upon the inner end of which are borne a large number of slender filaments, each of which is composed of a large number of minute cells. Each of these cells contains at first ordinary granular protoplasm, which develops into a spirally coiled body, the *spermatozoid*. After this is developed, the cells of the outer layer separate, and the spermatozoids escape from the cells and move about in the water by means of two very delicate and slender cilia at one end.

3. The *fertilization* of the carposphere is accomplished by the spermatozoid entering an opening at the outer end of the carpogonium, and uniting with the carposphere.
4. After fertilization, the carposphere secretes a thick wall, becomes dark-colored, and forms a *carpospore*, which falls from the plant to the bottom of the pond or vessel, where it remains till favorable conditions for its development cause it to develop into a new plant.
5. The carpospore first develops into a filament with a single row of cells, from which the jointed stem of the plant is developed.

Motion, except in the spermatozoids, is not found, and the plant manifests no remarkable sensitiveness.

The mode of reproduction which we find in Chara is the basis of another group of plants, namely: —

BRANCH **CARPOPHYTA**: Plants whose sexual reproduction is by means of a carposphere, which is a germ-cell enclosed in a layer of surrounding cells called a carpogonium, and a spermatozoid which is developed in an antheridium of very various structure. The structure of the plant body and the method of asexual reproduction in this branch is still more various than in the previous branches. The classes are as follows: —

Class **Coleochæteæ**: includes small, green, fresh-water plants consisting of numerous densely branching filaments of cells placed end to end. Asexual reproduction is by means of zoöspores, which arise from the protoplasm of the filament-cells. The single genus Coleochæte represents this class.

Class **Florideæ** comprises the bright-colored sea-weeds generally known as "sea mosses." In these the asexual

reproduction is by means of *tetraspores*, — so called because the contents of certain cells divide into four so-called daughter cells, which are the source of a new generation of plants.

Class **Ascomycetes** includes an enormous number of species, in which the carpospore develops into a mycelium, sometimes of large size, upon which is formed a structure of more or less complexity called the *sporocarp*, upon which develop the cells called asci, the contents of which break up into the ascospores. These plants vary very greatly in the method of forming asexual spores. Here belong the Eurotium and Penicillium mentioned in Chapter IX., and other allied molds, various forms of blights, the truffles and cup fungi, as Tuber and Peziza; certain mushrooms, as Ascobalus, Morchella, Helvella, etc.; the black-knot of cherry and plum trees; the many forms of lichens that cover trees, rocks, and fences; and the rusts and smuts that form such destructive diseases upon plants. The life history of many of these is not well known, and the classification is now in a very unsettled state.

Class **Basidomycetes** includes those carpophytes which produce spores from the end of certain cells called *basidia*, which are generally arranged in a layer called a hymenium, which is borne upon the inner surface of a hollow sporoscarp, or upon plate organs, called "gills," developed upon the under side of the disk-shaped sporocarp. Here are placed the "puff-balls," as Lycoperdon; "earth-stars," as Geaster; and "toad-stools," as Agaricus, Polyporus, Boletus, Hydnum, Clavaria, etc.

Class **Characeæ** includes Chara and Nitella, forms of green fresh-water plants, in which for the first time the plant consists of a true stem, and organs which prophesy the branches and leaves of higher plants.

CHAPTER XI.

A SPONGE (*Grantia ciliata*).

THIS sponge is found abundantly on the Northern Atlantic coast north of Vineyard Sound, in clusters of small cylindrical individuals not over an inch in length. These should be collected and preserved in alcohol for use.

MORPHOLOGY. — With a simple lens examine one of the sponges for the following points, viz: —

I. The cylindrical external form of the sponge body, by one end of which it is attached. Note: —

1. The outer surface is beset with numerous needle-like bodies called *spicules*.
2. At the free end there is a circle or *crown* of longer spicules.
3. Within the circle is an opening, called the *osculum*, leading to a central cavity or *cloaca*. The body is therefore a hollow cylinder or tube closed at the lower end but open at its free end.
4. At the base may be found buds which represent new sponge bodies in process of formation.

II. By tearing the sponge apart carefully with needles the structure can be still more minutely studied, and the following discerned, viz: —

1. The framework of spicules which supports the sponge flesh is composed of numerous hard spicules of which the external spicules mentioned above are the protruding portions.

a. Boil a portion of the sponge in a test tube of solution of caustic potash. Take a drop of the sediment from this solution and examine it with a high power of the microscope. It will be found to consist of minute spicules of various forms which should be carefully studied and sketched.

b. Carefully wash a portion of the sediment in water and pour upon a little acid. The effervescence is due to the setting free of carbon-dioxide. The spicule is composed of carbonate of lime, which is decomposed by the acid. The spicule soon disappears.

2. On the inner surface of the body wall may be seen with a lens minute openings which will be found to be tubes passing through the wall. These are the radiating *pores* through which the water passes to the cloaca and out at the osculum.

III. Prepare sections of a sponge as follows. For this purpose perfectly fresh specimens should be killed with picric acid, and left to stand ten to twelve hours in the acid, and then placed successively in fifty, seventy, and ninety-five per cent alcohol for twenty-four hours each. From this they should be transferred, first to a weak solution of celloidin for twelve hours and an equal length of time in strong celloidin. After the object has become thoroughly saturated it should be placed in a paper tray of thick celloidin, and when the top of the celloidin has stiffened a little the whole placed in a jar of eighty per cent alcohol and left to harden. When hard, thin sections may be made with a razor, either by hand or with a microtome, and kept in alcohol for use. When needed for study they may be stained with any of

the ordinary staining-fluids, cleaned in chloroform, and mounted in balsam for study. (If specimens for a large class are needed, it will be a saving of time and patience for the demonstrator or teacher to make the sections beforehand.)

The specimen may be stained after it has been soaked in seventy per cent alcohol, and then the tray of celloidin can be placed in chloroform instead of eighty per cent alcohol. After it is hardened it should be placed in oil of thyme or some similar oil until it is quite transparent, when it may be cut and mounted directly in balsam for study.

Both longitudinal and transverse sections should be made. From these note the following, viz.: —

1. The structure of the body-wall.
   a. The mass of the wall consists of not very clearly distinguished cells, which may be recognized by the numerous nuclei scattered through the protoplasm, most clear where they cover the outer surface and line the cloaca. These are the *ectoderm* cells, and constitute what is called the *syncytium.*
   b. The remains of the spicules imbedded in the syncytium.
   c. The more clearly distinguishable cells which line the radiating pores. These are the *endoderm* cells.
   d. In very well preserved specimens each of these endoderm cells may be seen to possess a single *cilium.*
   e. Occasional large cells which lie just beneath the endoderm cells lining the pores. These are the germ cells or *ova.*

f. In many sponges the syncytium is differentiated into two layers, an outer *ectoderm* and an inner *mesoderm.*

PHYSIOLOGY. — The sponge body consists of a number of cells united in a colony, and still largely independent of one another. A slight differentiation of form occurs, as we have seen, and this probably corresponds to a small differentiation of function.

I. Nutrition is probably accomplished mainly through the endoderm cells. These have the power to take up nourishment and transmit it to the other cells. In the larger sponges the tubes are much more complex, and therefore bring the endoderm cells into close proximity to the various regions of the body. The multiplication of cells by division here results in the increase of the size of the sponge body. This may be so rapid in certain localities as to result in the formation of buds which eventually become new sponge bodies, which do not, however, become entirely separated from the parent stock.

II. Reproduction is accomplished by a process similar to that already described in vorticella, except that there is greater differentiation in the reproductive elements. These consist of two kinds of cells, — the *germ cell* and the *sperm cell,* both of which arise from the cells of the syncytium.

1. The germ cell becomes larger than the surrounding cells and is called the *ovum* at maturity, when it breaks away from the other cells and is set free in the canals of the sponge body. This ovum is a complete cell, with nucleus and cell protoplasm enclosed in a delicate cell-wall.

2. The sperm cell originates like the germ cell, but when it reaches maturity its protoplasm breaks up into numerous small bodies, called *spermatozoa*, each of which consists of a head, to which is attached a long *flagellum*, by the vibration of which the spermatozoön is kept in active motion. The spermatozoön is probably a nucleus, with little surrounding protoplasm.
3. By its incessant motion a spermatozoön comes into contact with an ovum, penetrates its protoplasm and unites with its nucleus. This process is called fertilization. Compare this with the process of conjugation in Paramœcium and Vorticella.
4. After fertilization the ovum undergoes a process of *segmentation*. This begins in the separation of the nucleus into two nuclei, which is followed by the division of the whole cell-contents into two cells. Each of these again divides into two, and the process continues until a mass of cells is formed, from which is developed the young sponge. (The development of the embryo may be best studied in some other form at a later stage of study.)

III. *Motion.*—The sponge is fixed, except in its early embryonic stages, hence no organs of locomotion are found. The embryo moves by means of vibratile cilia with which it is provided. In the adult the cilia which are found on the cells which line the radiating pores produce inward currents of water, by means of which food is brought to the nutritive cells. Moreover, most of the cells are capable of amœboid movements. This enables the endoderm cells to injest food parti-

cles preparatory to appropriating them to the nutrition of the body.

IV. Sensation seems not to be specialized unless the ectoderm cells may be slightly more sensatile than the others.

The sponge just studied is a representative of a group of animals known as : —

BRANCH **PORIFERA** : This includes animals, each of which consists of a mass of cells in which at least two layers may be distinguished, the ectoderm and endoderm, with sometimes a third layer called the mesoderm lying between the other two. Through this mass of cells is a more or less complex system of canals, carrying water from which food is taken. The branch includes only : —

Class **Spongida**, comprising the various forms of sponges.

CHAPTER XII.

FRESH-WATER HYDRA (*Hydra viridis* or *fusca*).

FRESH-WATER hydras of either of the above species may be found in almost any stagnant pond. If a small net of thin muslin be scraped over the grass or lily-pads in such a pond and the contents washed out into a glass jar, after a short time hydras will generally be found adhering to the sides of the jar. When fully extended a hydra consists of a stem-like body half an inch or more in length and of the diameter of a common pin. Around the end not attached to the jar a number of delicate, thread-like tentacles will be seen. The least disturbance will usually cause the hydras to contract, so that they cannot be seen when first caught; and repeated efforts will sometimes be necessary before any will be collected. When they are to be studied one should be gently transferred to a watch-glass of fresh water and allowed to remain quiet for a few minutes until it is well expanded, when it may be examined, first with a simple lens, and afterward with the low power of the compound microscope.

MORPHOLOGY. — I. *External form.* Observe: —

1. The long and slender body. This consists of a tube, the walls of which consist of two layers through which the central cavity may be seen easily in H. fusca, but with difficulty in H. viridis.

2. The attached end is flattened against the object to which it is attached, forming a sort of disk by which it holds firmly to its support.
3. Around the free end of the body is a circle of slender *tentacles*, which when fully expanded are considerably longer than the body.
4. Within this circle of tentacles the body tube projects slightly, forming the *proboscis* or *manubrium*.
5. In the centre of this proboscis is the *mouth*, a small opening leading into the body cavity.

II. Examine the structure of the body-wall and the tentacles with the low power of the microscope. They are composed of two layers, an outer more transparent layer, the *ectoderm*, and an inner more opaque layer, the *endoderm*.

1. Note the form and structure of the cells which make up the ectoderm. Each consists of:—
   a. A well-defined but variously shaped mass of protoplasm, with scarcely any differentiation.
   b. A clearly distinguishable nucleus and nucleolus in the protoplasm mass.
   c. A delicate cell-wall enclosing the protoplasm.
2. Within or among the ectoderm cells may be found numerous pear-shaped bodies, with the smaller and pointed end usually projecting somewhat beyond the general surface of the ectoderm cells. These are the *nematocysts*, or thread-cells, and consist of the following parts: —
   a. An outer covering from one end of which
   b. A barbed point projects.
   c. With this barbed point a coiled filament is connected. Pressure upon the outer covering

will force out this barb-pointed filament to its full length. This barb produces an irritating or stinging effect upon other animals, and probably aids the hydra in capturing its prey.

3. The inner layer, or endoderm, consists of a single layer of cells. These differ from the ectoderm cells in the following respects: —

a. They are not permanent in form, but are capable of amœbiform movements.

b. They are frequently possessed of vibratile cilia.

c. In H. viridis they contain chlorophyl granules; in H. fusca, dark granules.

III. Crush a hydra gently under the cover glass, or better, tear it out with needles before putting on the cover glass, and then examine the various elements of which the body and tentacles are composed as indicated under number II., noting specially 2 *b*, and *c*, and 3 *b*.

IV. Run a drop of safranin solution under the cover glass, and observe the effect upon the nuclei of the various cells.

V. Prepare sections of hydra as follows: Kill a hydra by dropping picric acid, mercuric chloride solution or some other poison into the water containing it. When a fairly well-expanded specimen is obtained place it for a short time (30 to 60 minutes) successively in 30, 50, 70, and 95 per cent alcohol, and then imbed and cut sections as directed in the previous chapter. These sections may be kept in 80 per cent alcohol until wanted for use. They may be stained as desired by any of the ordinary staining-fluids used in the labo-

ratory. For many purposes eosin is satisfactory, as it does not stain the celloidin. When wanted for study the sections must be placed for five or ten minutes in 95 per cent alcohol, and then soaked in chloroform until clear, and mounted in a drop of balsam for examination.

1. Note the two layers of the body-wall.
   a. The somewhat regular form of the ectoderm cells.
   b. The irregular form of the endoderm cells.
   c. The arrangement of the nematocysts in various stages of development.
   d. The inner ends of the ectoderm cells are prolonged into delicate filaments, which are turned to the side between the two layers, and form a sort of network of fibres whose special function seems to be contraction.
2. The central space, or body cavity.
   a. Its nearly uniform size wherever the section be taken.
   b. The tentacles are hollow and communicate with the central cavity.

PHYSIOLOGY. — A. *Nutrition.* Watch the movement of the hydra in search of food. When the tentacles come in contact with any particle of food, as a small animal, it is entangled by the barbs and held until it can be drawn to the mouth and swallowed. The cells of the endoderm by their amœboid movements probably engulf small particles of food, and thus digest and absorb them in the same manner as the single-celled amœba. The other cells receive nourishment from these by osmosis. It is possible that the endo-

derm cells also digest food that is not engulfed by them, and afterwards absorb the digested substance. The absorbed matter is then changed into protoplasm by a process called *assimilation.*

B. *Reproduction.* This process is accomplished by two methods: —

I. The most common is the asexual process of budding. Hydras will be found with smaller hydras attached to their sides. These originate as follows: —

1. A slight protrusion appears on the side of the body of the hydra near the middle, and increases in size until it assumes the form of the parent body in miniature.
2. Tentacles appear at the distal end of the bud.
3. A mouth opening is formed within the circle of tentacles.
4. The base of the bud becomes constricted, and the bud finally separates from the parent body and attaches itself to some object, thereby forming a distinct individual, capable of repeating this process.

II. Another process of reproduction consists of the development of two sorts of reproductive cells: the germ cell, called the *ovum*, and fertilizing or sperm cell, called the *spermatozoön*, by the union of which a cell is formed which develops into an embryo. Search for a hydra upon the body-wall of which, near the lower or basal portion, is a rounded bunch or swelling, the *ovary*. This will be distinguished from the buds already described by the absence of the green layer which is always present in the asexual reproductive buds.

1. Examination will show this ovary to be composed of: —
   a. An outer layer of ectoderm cells, called the germ sac.
   b. A larger germ cell called the *ovum*.
2. Nearer the mouth may be found, oftentimes in the same animal, another slightly different swelling, generally of a smaller size, which is the *testis*. This consists of: —
   a. A layer of ectoderm cells like those of the ovary.
   b. An inner cell which at its maturity breaks up into a number of small bodies, each of which consists of a small mass of protoplasm containing a nucleus, and provided with a long and freely vibratile tail, by the motion of which the body is moved from place to place through the water. This body is called the *spermatozoön*.

If a mature testis be crushed under the cover-glass there will be found under the glass a large number of these actively moving bodies. Measure them and note the results. When these spermatozoa are matured the enclosing wall bursts and they are set free. Propelled by means of the vibrating filament, they at last come in contact with the sac of the ovary, through which they make their way and come in contact with the ovum. This one of them penetrates, during which process the tail is absorbed and the nuclei of the ovum and spermatozoön coalesce. This process is called the *fertilization* of the ovum. Compare this process with the conjugation of two exactly similar cells in Vorticella and Spirogyra. For a more detailed account of the varied

phenomena connected with the process of fertilization see Balfour's "Embryology."

The history of the ovum after fertilization is as follows: The cell nucleus, called here the germinal spot, first divides, and this is followed by the division of the whole mass into two perfect cells, each containing a nucleus. Each of these repeats the process, forming four, eight, sixteen, etc., cells. This is called *segmentation* of the ovum. By means of nourishment received from surrounding cells the embryo has during the process increased in size, and the cells are arranged in a globular form to which the name *morula*, or *mulberry stage*, is given. These cells arrange themselves in a layer around a central cavity, thus forming a hollow sphere called the *blastosphere*, and the layer of cells is called the *blastoderm*. The cells of this blastoderm now divide in such a way as to form two layers, the outer of which is called the *epiblast*, and the inner the *hypoblast*. This is called the *gastrula stage* of the embryo. The cells of the epiblast develop cilia upon their outer surfaces, which by their motion and the movements of the embryo itself burst open the sac in which the embryo has thus far been held, and it floats away a free-moving larva, to which the name *planula* is applied.

After moving about freely for a time by means of the cilia the embryo settles down upon one end, which becomes attached to some solid body, the cilia are absorbed, a mouth is opened at the free end, the wall is pushed out in spots around the mouth to form a circle of tentacles, and the embryo becomes a complete hydra polyp.

C. *Motion.* While the hydra is ordinarily fixed, it is capable of very noticeable movements. These are

accomplished, mainly, by the contraction of the cells of which the ectoderm is composed, but especially by the agency of the fibrous prolongations of the inner ends of these cells, which appear to be a sort of primitive muscular fibre. Hydra is also capable of locomotion. Letting go its hold with the disk-like lower end of the body and curving the body so that the tentacles come in contact with the object to which it is attached, it is able to creep slowly from place to place. If left upon the dark side of the jar it will often be found a little later on the side which is turned toward the light.

D. *Sensation.* The least jar communicated to the vessel which contains a hydra is almost certain to make it contract, showing thereby that it is exceedingly sensitive. The tentacles seem to be specially sensitive, but this sensatility seems to lie in the ordinary ectoderm cells, and is therefore specialized and localized to a very slight degree. There are, however, among the nematocysts certain hairs the disturbance of which may communicate sensation to the protoplasm of which they are the prolongations.

Hydra represents another very large and important group of animals known as —

Branch **CŒLENTERATA**: Animals consisting of a body-wall composed of at least two distinct layers, ectoderm and endoderm, with sometimes a mesoderm, enclosing a body cavity into which the mouth opens. Nematocysts occur in various parts of the body. Around the mouth is a circle of tentacles for purposes of prehension. These parts are all arranged in a radial plan.

Class **Hydrozoa** includes those forms in which the mouth opens directly into the body cavity, and is represented by the hydroids, Portuguese man-of-war, and the Jelly-fishes.

Class **Anthozoa** includes those forms in which the mouth opens into an invaginated sac, or stomach, at the bottom of which is an opening into the body cavity. Here belong the sea anemones and coral polyps.

Class **Ctenophora** includes forms which have the body cavity more or less branched into a vascular system and possess eight external bands of vibrating plates. The Ctenophores constitute this class of animals.

CHAPTER XIII.

A LIVERWORT (*Marchantia polymorpha*).

THE odd group of plants called liverworts present a very interesting phase of advancement in vegetal life. This species, or a species of Lunularia which closely resembles Marchantia in most respects, may be easily found for study. Marchantia has cup-shaped, and Lunularia crescent-shaped cupules. The plants grow in dense mats of broad, deep-green, leaf-like bodies, generally completely covering the ground. These should be taken up in a mass and kept in a moist atmosphere (under a glass cover) until needed for use. They may often be found in greenhouses, where they become a great nuisance. The sexual reproduction occurs in mid-summer. The plants with the sexual organs should therefore be collected at that time and preserved in alcohol for study.

MORPHOLOGY. — A. *General Anatomy.* Wash the plant gently and with the aid of a lens, when necessary, examine it for the following characteristics. Observe:

I. The plant body, broad and flat, called a *thallus.*

1. The branching of the thallus into two equal parts, shown in all except the younger thalli. This is called *dichotomous* branching.
2. The wrinkled edge of the thallus, due to the more rapid growth of cells upon the outer edge.

3. The cup-shaped (semilunar in Lunularia) organs, *cupules*, of the asexual reproduction, containing minute green bodies, the *gemmæ*, which fall out and develop into new thalli.
4. In plants gathered in mid-summer the receptacles which bear the organs of sexual reproduction may be found. These are borne on pedicels at the end of the thallus, and are of two sorts: one flat on the top with crenate margins, the *antheridial* receptacle; the other star-shaped, with hairy fingers from the under side of each ray, the *archegonial* receptacle. They are also *diœcious*, that is, the two kinds are borne on different plants.

II. The upper surface of the thallus. Note its dotted appearance. Examine with a lens and observe: —

1. The lozenge-shaped areas, *areolæ*, which spread over the whole surface. Study each areola and ascertain its general structure, namely, —
   a. The depression along the lines which separate the areolæ.
   b. The slightly raised surface within these lines.
   c. The minute pore, *stoma*, in the centre of each areola.
2. With a sharp razor shave off the thinnest possible portion of the surface, avoiding the green cells which lie immediately under the surface. Several experiments will probably be necessary before the beginner can make a sufficiently thin section to include only the surface cells. Put a drop of water on a slide, place the thin section in it, and cover with the thin cover glass. The transparent cells of the surface constitute

the epidermal tissue. In the areola these are of four sorts, distinguishable from, but perceptibly shading into one another.

a. The general form, about as broad as long, filling the most of the areola.

b. The more elongated cells which lie along the lines which separate the areolæ.

c. The gradually curving cells near the stoma.

d. The curved *guard-cells*, which form the border of the stoma.

III. The under surface. Prepare as before a thin surface-section and examine first under the low power.

1. The cells of the under epidermis are of one general sort.

2. The minute hair-like cells, *rhizoids*, which project from the surface, with the basal end among the ordinary epidermis cells and forming a part of the epidermal system.

   a. Notice that some of the rhizoids are clear and transparent.

   b. Others have minute projections from the wall into the cavity of the cell, with knob-like ends.

3. Thin *scales*, which will be seen to consist of a thin layer of smaller cells united to the epidermis.

4. It will be seen that the border of the thallus consists of a row of transparent cells only.

IV. Make a cross-section of a thallus by placing it between two pieces of pith, and shaving off with the razor a very thin slice of pith and thallus so as to make a thin section across the thallus. Place this in a drop of water under a cover glass and examine. Observe

with low power the general arrangement of the tissues which make up the thickness of the thallus.

1. *The Epidermal System.*
   a. The somewhat flattened and nearly colorless cells on the upper surface. This is the upper epidermis.
   b. Their slight elevation above the other cells, except at certain points of attachment, along the lines between the areolæ.
   c. At the highest point of elevation in the areola there is an opening, the stoma, through the epidermis, the cells around which are arranged in a barrel-shaped opening. (In Lunularia the cells are more simply arranged in a single layer.)
   d. The lower epidermis is without stomata.
   e. The occasional greatly elongated hair-like cells, the bases of which are imbedded among the cells of the lower epidermis. These are the rhizoids, or root-hairs. Note the two forms above-named.
   f. The structure and connection of the scales, which are also found upon the under surface.
2. *The Fundamental System, or Parenchyma.*
   a. The nearly colorless cells which make up the lower layers of the thallus. These are thin-walled cells and make a greater thickness in the middle of the thallus. These constitute the colorless *parenchyma.*
   b. The layer of cells just beneath the upper epidermis. These are packed closely together and filled with chlorophyl and numerous

chlorophyl bodies, and are called chlorophyl-bearing parenchyma.

c. The loose chlorophyl-bearing parenchyma cells which lie just beneath the stoma, and extend upward into the space below the raised epidermis.

B. *Reproductive Organs.* — I. The *cupules and gemmæ.* Make a thin section through a cupule and examine it.

1. With a low power observe the position and attachment of the gemmæ.
   a. They are an outgrowth of the epidermis, each attached by a short stem.
   b. They may be seen in all stages of growth, from minute bodies of one cell to full-grown gemmæ.
2. Observe the form and structure of the cupule.
   a. The epidermal cells on both inside and outside of the cupule.
   b. The irregular margin of the cupule.
   c. The position and arrangement of parenchyma.
3. Scrape off some of the gemmæ and examine them with the high power. Notice: —
   a. The form, notched on each side; the short stem.
   b. The cell structure of the gemma.
4. Gemmæ may usually be found in process of development into thalli, and the transition of the form of the gemma into that of the mature thallus observed.

II. *Sexual Reproductive Organs.* Examine the specimens which have been collected for study and preserved in alcohol. These consist of two sets of organs: —

1. The *antheridial disk* has a flat top, and a scalloped margin, and is borne upon a short pedicel which grows from the margin of the thallus. In the top of this disk are borne the *antheridia* which consist of nearly globular bodies composed of an outer wall of cells in a single layer, enclosing a number of minute sperm cells. Each of these sperm cells contains a single spermatozoid, a long thread-like mass of protoplasm, armed at the end with two vibratile cilia. Make a thin vertical section of the disk and examine these parts.
2. The *archegonial receptacle* consists of a star-shaped body borne on a slender stem. On the lower surface of this receptacle and surrounded by minute hairs the *archegonia* are developed. Each of these is at first a single cell, which soon divides into a number of cells and forms an enclosing wall surrounding a single germ cell. This germ cell is fertilized by contact with an antherozoid, after which it develops into a sac called a *sporogonium*, which encloses a large number of spores, and numerous elongated bodies called *elaters*. The spores escape from the sporogonium and develop into new thalli.

Marchantia represents a group of plants called, —

BRANCH **BRYOPHYTA**: These are plants whose organs of sexual reproduction consist of an archegonium and an antheridium, producing respectively the germ cell and sperm cell. Two well-distinguished classes are made: —

Class **Hepaticæ**, in which the plant body is a flat, leaf-like structure called a thallus. Here belong the liverworts and allied forms.

Class **Musci**, in which the plant body consists of a well-developed stem with simple leaf-like organs borne upon its sides. The cell structure of the stem is more complex than Marchantia. Here belong the mosses, of which there are many species.

CHAPTER XIV.

THE SHIELD FERN (*Aspidium acrostichoides*).

THE ferns constitute a very interesting group of plants, not only from their variety and beauty, but also from their structure. Among the best forms for study are the "evergreen shield fern" (Aspidium acrostichoides), and the "common brake" (Pteris aquilina). The former can be collected at all times of the year, when not covered by snow, and is therefore more convenient for study. The rhizomes, however, are so thickly covered with the black bases of the old fronds that they can be studied only with difficulty. It is, therefore, better to collect a quantity of the rhizomes of Pteris, and preserve them in alcohol for future use when the fronds have disappeared and there is nothing to mark the location of rhizomes. Some of the fertile fronds of the Aspidium should also be gathered when they are in fruit, but before the spores fall, and preserved, some in alcohol and others by pressing. If they are to be studied by a class of students in the laboratory, a few specimens of the whole plant should be procured, so that all may see the various parts and their relation to one another. Fresh fronds, both fertile and sterile, should be provided in abundance and variety of form.

MORPHOLOGY.— A. *Macroscopic Anatomy.* The plant consists of three distinct portions, the *root*, the *stem*, and the *frond*.

I. The stem is usually entirely underground, and consists of a short and black woody portion, which in Aspidium is almost always completely covered with the blackened bases of dead fronds. In Pteris, it is more free from them, and hence better for study. This stem is called a *rhizome*. It increases in length by a growing bud, which always terminates the rhizome, and from which the new fronds spring.

II. The *roots* are borne on the sides of this rhizome, and are therefore *secondary* roots. The *primary* root, which is found only in very young plants, grows at the end of the stem, and very soon decays, leaving its work to be done by the secondary roots.

III. There are borne, near the growing end of the rhizome, the leaf-like green portions of the plant, called *fronds*. Those at the end of the rhizome are smaller and younger, and new fronds may be seen coming from the bud at the end, if taken in early summer when the growth is vigorous.

1. Observe the peculiar method of the unfolding of the frond from the bud. The arrangement of the leaf or frond of a plant in the bud is called its *vernation*. This particular arrangement is characteristic of the ferns, and is called *circinate* vernation.
2. The central stalk or axis of the frond is called the *rachis*. It is more or less covered with thin brown scales upon its otherwise smooth surface.
3. The flattened green portion of the frond is the *blade*, and in this fern is divided into a large number of lobes, which are alternately arranged on the opposite sides of the rachis. These are

called *pinnæ*. Each pinna consists of the following parts: —

a. The central axis of each pinna is called the *midrib*. This will be seen to be a branch of the rachis.

b. The *veins*, which branch from either side of the midrib.

c. These again branch into *veinlets*. Observe the direction and termination of these veinlets in a continuous *marginal veinlet*.

d. The *blade* of the pinna, consisting of a green leaf-like portion, for which the midrib, veins, and veinlets constitute a supporting framework.

4. Certain of the fronds have the upper pinnæ contracted, and bearing upon their back masses of brown organs, which constitute the so-called fruit. These fronds are called *fertile*, in distinction from the ordinary, or *sterile*, fronds. The separate mass of fruit is best distinguished upon the upper pinnæ, or in immature fronds. Each of these masses is called a *sorus*, and consists of —

a. A thin membrane, which originally covers all the other parts, but which becomes shrivelled to a dry, brown mass in the centre of the sorus before the maturity of the fruit. This is called the *indusium*. These may be found in the various stages of development. Note the attachment of the indusium to the surface of the frond.

b. Around the base of the indusium, or projecting from the edges of the partly spread indusium,

may be seen the numerous ***sporangia***. Each sporangium consists of a sac supported upon a slender stalk. Examine the sporangium with a low power of the microscope. It will be seen that it is made up of a thin membrane, with a dense opaque and scalloped border, which extends from the top of the stalk, round the surface of the sporangium, nearly to the stalk again. This is called the ***annulus***. In the drying of the sporangium at maturity, this annulus tends to curve outward, until the tension ruptures the thin membrane of the sporangium and scatters its contents. This consists of a number of ***spores***, into which the protoplasm of the inner cell has been broken up.

B. *Microscopic Anatomy.*

I. *Of the Rhizome.* — Taking the rhizome of the common brake (Pteris aquilina), either fresh or preserved in alcohol, and from which all grit has been carefully removed, with a sharp razor cut a very thin transverse section. Examine this first without a microscope, or with a simple lens, and note the form and appearance of the section. Make a sketch of the appearance. Examine it with the high power, and note the following tissues, namely: —

1. A single row of cells on the outer edge forms the *epidermis*.
    - *a.* These cells have the outer wall thicker than the lateral, or inner walls.
    - *b.* The protoplasm is filled with minute granules. Test with iodine to determine the nature of these granules.

2. Just within the epidermis is a broader area of darker, thick-walled cells, called *schlerenchyma* cells. Look with care for the line which separates the walls of two adjacent cells. These cells constitute a *cortical* layer.
3. Within the cortical layer is a mass of thin-walled cells called *parenchyma* cells. These cells are filled with granules similar to those of the epidermis, but much more densely crowded. What does the iodine test show the granules to be? Parenchyma is the simplest form of plant tissue.
4. In the centre of the parenchyma is an oval, circular, or crescent-shaped area of tissue, called the *fibrovascular bundle.* A very thin section of this will show that it is made up of the following kinds of cells.
   a. A single row of cells, generally easily distinguished from the parenchyma cells adjacent to them, surrounds the area. This constitutes the *bundle sheath.* Note the forms of the cells.
   b. Immediately within the bundle sheath is usually one or more rows of small parenchyma cells enclosing one or more rows of small cells with thicker walls, called *bast* cells, or *fibrous tissue.*
   c. Among these bast cells, generally nearer the centre, are occasional larger clear cells, and of more or less irregular outline, often accompanied by small parenchyma cells. These are the so-called *sieve* cells.
   d. The bast and sieve cells with their accompany-

ing parenchyma cells are sometimes called the *phloëm*.

e. Within the areas already named are certain large and thick-walled cells with much flattened sides and angular outline. These are the *scalariform vessels*. Note that they are empty.

f. Among these scalariform cells along with small clusters of parenchyma cells will be found occasional smaller and more nearly circular cells, in which will sometimes be seen a loosened coil. These are *spiral* cells.

g. The scalariform and spiral cells with their accompanying parenchyma constitute what is sometimes called the *xylem*, or woody portion of the bundle.

5. Make a longitudinal section of the rhizome, and compare the areas and different kinds of cells with those of the transverse section. Note especially those cells in which the appearance is different from that of the transverse section.

a. The arrangement and form of the bast cells.

b. The form of the sieve cells.

c. The form and markings of the scalariform cells. Examine carefully the cut walls of a cell and determine what the peculiar markings indicate. Note an occasional ring-like thickening of the wall which marks the remains of an absorbed end-wall, the disappearance of which has united several cells into a continuous vessel.

II. *Of the stipe.* — Make a thin transverse section of the stipe and examine it first with the low power. Note

the following areas. Make a small drawing of the whole section (× about 5) showing their arrangement, and then examine each area and determine the structure and arrangement of the cells in each. The section will be better for study if it is soaked for a time in oil of cloves before examining it with the microscope.

1. The thin *epidermis* which surrounds the whole stipe. This consists of small cells with greatly thickened outer walls of the more or less flattened sides and arranged in a single layer.
2. Beneath the epidermis is a layer of greater thickness, composed of thick-walled cells of various sizes and forms, more irregularly packed together, and constituting a kind of tissue called *schlerenchyma*. Both these cells have their walls thickened at the expense of the protoplasm, having the cavities very small. The lines which divide the walls of two adjacent cells can be distinguished with care.
3. The central portion of the stipe is mainly occupied by a mass of cells with thin walls and filled with protoplasm. These contain in their protoplasm numerous minute bodies. These cells constitute what is called the *parenchyma* tissue, the cells of which still retain their primitive form and structure.
4. In the midst of the parenchyma cells are from three to five areas of much smaller cells of various kinds. These areas are transverse sections of the *fibrovascular bundles*. These are so called on account of the forms of cells of which they are composed.

a. A circle of cells scarcely different from the sur-

rounding parenchyma cells encloses the whole bundle and constitutes the *bundle sheath.*

b. Within the bundle sheath are found certain small cells, with thicker walls and very little cell cavity. These are cross-sections of the *bast* or *fibrous* cells. The layer is very irregular, and the cells are also mingled with the other cells of the bundle.

c. A portion of the centre of the bundle is occupied with cells of a much larger but varying size. These are the vascular cells. They are here seen as cross-sections and do not show their characteristic differences very clearly. These are the sieve, spiral, and scalariform cells, already described in the rhizome, from the fibrovascular bundle of which the bundle of the stipe is derived.

5. Make several sections just below one of the pinnæ and lay them out in order so as to see the branching of the fibrovascular bundle to the mid-rib of the pinna. If the first effort does not show this, the sections were not begun far enough down the stipe, and you should continue the sections to the next pinna.

6. Make now a longitudinal section of the stipe and examine it in the same way as before. If the section is through one of the bundles, the same series of cells will be seen as in the transverse sections. It will be more convenient to make sections of the whole stipe at first, and after studying the epidermis, schlerenchyma, and parenchyma, make a very much thinner section of the bundles without reference to the rest of

the stipe. The various tissues will present quite different appearances in these sections.

a. The epidermis cells are seen to be very greatly elongated cells, which are united to one another at the ends by overlapping. A shaving from the surface of the stipe, so thin as to cut only the epidermis, should be examined to make this clear.

b. The schlerenchyma cells are also greatly elongated and tapering cells, the conical ends of which so interlock as to make a very tough tissue.

c. The parenchyma cells, though not perfectly spherical in outline, are only slightly elongated.

d. The fibrous (or bast) cells are greatly elongated, and have tapering ends which wedge between one another and give the fibrous character to the bundle.

e. The sieve cells are larger cells with the walls dotted with thinner spots variously situated.

f. The spiral cells consist of a cell with the wall thickened, with a spiral thread which is sometimes torn loose in making the section.

g. The scalariform or ladder cells have their walls marked by transverse bars of thickened wall, between which are irregular transparent thin spaces.

h. The bundle sheath cannot be easily distinguished from the parenchyma cells.

III. *Of the Frond.* Make a thin transverse section of a pinna by holding the pinna between two pieces of pith, and cutting both pith and pinna with a sharp razor; a thin section will show the following structure:

1. The flattened cells of the epidermis on both the upper and under sides.
2. The layer of chlorophyl-bearing cells just beneath the upper epidermis, elongated in a direction at right angles to the surface, and packed closely together, gives the dark-green color to this surface.
3. The remaining cells are more loosely situated. The cells are irregular and branching, touching one another only at certain points, and leaving large spaces between the cells. These cells only loosely rest on the under epidermis. The spaces are in communication with the external air by means of the *stomata* in the under epidermis.
4. Find the transverse section of the mid-rib of the pinna, and note its similarity to the fibrovascular bundles. If the section is made to include one of the veinlets, that also will be seen to contain some of the same structure.
5. With a sharp knife or razor start up a bit of the lower epidermis and strip it off. Examine this under the microscope with the outer side up. Observe —
   a. The irregular outline of the epidermis cells.
   b. The pairs of crescent-shaped cells, *guard-cells*, which lie among the other cells. These have their convex edges turned toward one another so as to leave an opening, the *stoma*, between them. Observe the direction of the long axis of the cells. The stoma is the means of communication between the spaces among the loose cells of the body of the

pinna and the external air. Through these stomata the gases of the air are taken in for the nourishment of the plant-tissues and moisture is also exhaled. These stomata are found in all the higher plants. Their curved form may be increased by the absorption of moisture, and the lengthening of the cell, and *vice versa.* In this way some plants are protected from excessive evaporation of moisture by the shrinking of the guard-cells and closing of the stomata during severe drought.

c. The cells of the epidermis which lie over the mid-rib are somewhat more elongated.

d. Turn the epidermis over and examine the green cells which have been torn off with it.

6. After stripping off the under epidermis from a portion of a pinna, carefully rub off the green cells of the leaf with a not too sharp knife-edge until the upper epidermis is laid bare. When sufficiently transparent, examine it with the microscope. Notice its similarity to the under epidermis, with the exception of the absence of stomata.

7. Examine a fresh indusium and ascertain its cell structure. What sort of tissue is it like?

8. Examine a sporangium and make out its structure, noting: —

a. The thin cells of the sporangium wall.

b. The thick-walled cells of the annulus.

c. The stalk of the sporangium.

d. The attachment of the stalk to the epidermis.

PHYSIOLOGY. — I. *Nutrition.* The roots of the fern absorb water from the soil, together with whatever

of mineral matter it may contain in solution. This must be distributed throughout the plant by osmosis. In this function the vessels of the bundles serve an important office, since their greater length and the thin areas in their walls, particularly where the ends of the cells come together, make more rapid distribution possible. As already stated, the chlorophyl-bearing cells of the pinna absorb gases from the air, and they are decomposed by the action of sunlight in the presence of the chlorophyl.

II. *Reproduction.* This is accomplished in two ways, one asexual, the other sexual.

1. *By spores.* The sporangia described above are the organs of asexual reproduction. The young sporangium encloses a mass of protoplasm which, on the maturing of the sporangium, breaks up into a number of spores. When the sporangium is ripe the drying of the outer portions contracts the annulus and tends to straighten it. This produces a tension upon the thin wall of the sporangium, and at last it gives way at the point where the annulus does not reach round it. This rupture suddenly releases the annulus, and its springing back jerks the spores out of the sporangium, sending them a short distance from the plant. These spores, when they find favorable conditions of warmth and moisture, germinate and produce minute plants. This is as follows: each spore divides into two cells, and each of these divides again, until by multiplication and arrangement of the cells a minute plant called the *prothallus* is formed. This consists of a kidney-shaped mass

of cells, with minute hairs or rhizoids on the under side, by which the prothallus gets its nourishment. This prothallus produces the true sexual organs described below.

2. *By sexual organs.* These, like those of marchantia, are called the *archegonium* and *antheridium*. Both organs are borne on the under side of the same prothallus.
   a. The archegonium, like that of marchantia, consists of a number of cells arranged in a flask-shaped body, enclosing at its base the germ cell, and extending into a long tube open at its outer end.
   b. The antheridium consists of a small cluster of cells projecting from the surface of the prothallus and enclosing a cell which gives rise to several sperm cells. Each of these develops an elongated and spirally coiled spermatozoid.
   c. The spermatozoids escape and find their way down the tube of the archegonium, and fertilize the germ cell, which then develops into the minute plant which is called a "seedling," but which is a mature fern in miniature.

The fern is a representative of the

BRANCH **PTERIDOPHYTA.** These are plants with a clear distinction of root and stem, which bear more or less leaf-like organs. The sexual organs are borne upon small plants called prothalli, and consist of archegonia and antheridia.

Class **Equisetinæ** includes plants with hollow stems and very narrow leaves united into a cylindrical sheaf at the

nodes of the stems. Here belong the various forms of "horsetails" represented by the genus Equisetum.

Class **Filices** includes plants with a short, solid stem, often growing underground, and having broad and often beautifully divided leaf-like organs called fronds. Here belong the very large variety of "ferns" represented by a large number of genera, many of them of exquisite beauty, and some of enormous size.

Class **Lycopodinæ** includes plants with solid, branching stems, which bear small but well-formed sessile leaves. Here belong the "club mosses," as Lycopodum, Selaginella, etc.

BRANCH **SPERMOPHYTA** or **PHANEROGAMIA.** These are plants in which the sexual reproduction is by means of a germ-cell called an ovule, which is borne in an organ called a pistil, whose walls are composed of a complex tissue; and sperm-cells called pollen, which are borne in an organ called an anther. After the fertilization of the ovule by the pollen the ovule develops into an embryo plant called a seed, in which stage it may remain for a long time without losing its vitality. Under proper conditions of temperature and moisture this embryo plant develops into a mature plant. The reproductive organs are modified leaves, and are often surrounded by other modified leaves, which are called floral envelopes, in consequence of which the plants are often called flowering plants. The tissues of the Spermophyta are similar to those of the Pteridophyta, but more highly specialized.

Class **Gymnospermæ** includes those plants which develop the seeds upon the side of open pistils which closely overlie one another. Here belong the pines, spruces, and other allied forms.

Class **Angiospermæ** includes those plants in which the seed is developed in a closed seed-vessel or carpel. Here belong all the remaining flowering plants.

CHAPTER XV.

THE STAR-FISH (*Asterias vulgaris*).

STAR-FISH are everywhere abundant on the rocky sea-coast, in the tide-pools and on the sand below low-water mark. The most common species on the northern Atlantic coast is Asterias vulgaris, Stimp., but either of the other common species can be used equally as well. If living specimens can be obtained they are much more desirable for study, but if that is impossible either from location or the time of year when they are to be studied, specimens preserved in alcohol will answer nearly as well.

MORPHOLOGY. — A. *External Form.* The body consists of a central portion or *disk*, and five radiating arms or *rays*. The star-fish moves mouth downward and in any direction with equal facility. The ray opposite the madreporic plate is, however, called the anterior, and the others are called the lateral rays.

I. The oral surface, that on which the mouth is situated, shows the following characteristics: —

1. A central opening surrounded by a soft, muscular border. This is the *oral opening*, or mouth. At some distance away is the hard crust of this surface.
2. Five deep grooves run from the region of the mouth to the end of the five rays. These are the *ambulacral areas* or grooves. These grooves

contain numerous soft organs arranged in regular order. These are the *ambulacra*. Examine one under the simple lens and note its structure.

a. The hollow muscular tube.

b. The flattened or even concave and disk-like end. If live animals are studied watch the use of these organs.

3. The parts bordering the ambulacral areas.

a. First, a row of small spines on the border of the area.

b. A row of larger spines outside these.

c. A peculiar modification of the spines around the mouth.

II. The aboral surface, or that opposite the mouth.

1. The general appearance of the surface.

a. With a lens, examine and make an enlarged drawing of one of the larger spines, with the minute spines at its base.

b. Some of the smaller spines are forked at the end, the two divisions moving upon one another like jaws. These are called *pedicillariæ*.

2. Among the hard spines may be seen certain soft projections, which in the living animal are capable of muscular action and constitute the *aboral tentacles*.

3. A little to one side of the centre is a nearly round area without spines, but with certain definite markings of much regularity. This is the *madreporic plate*. Draw it enlarged.

B. *Internal Anatomy*. Cut along both sides and the outer end of two rays nearest the madreporic plate to the base, cutting at the angle between the rays,

using great care not to cut beyond the hard crust. Lift the loosened upper crust so as to see the internal organs.

I. The digestive system is situated in the central part of the disk and consists of the following parts.

1. A loose, baggy tube commencing with the mouth and ending at the aboral surface in the anal opening, which, however, is so closely contracted as to be found only with difficulty. This baggy tube is called the stomach. It is abruptly enlarged just above the mouth, and as abruptly contracted at the opposite end, thus forming a very broad, short tube quite through the body cavity and shut off from it.
2. In the oral side of each ray is a pouch-like lobe of the stomach, the closed end of which is attached by muscles to the central ridge of the floor of the ray. The stomach can be pushed out through the mouth and thus enclose food which it cannot swallow. These muscles serve to pull it back into place again.
3. In the aboral side of each ray the wall of the stomach is prolonged into a tube which soon divides into two branches, with each of which is connected a large number of small sacs, *hepatic coeca*, suspended from the top of the ray.
4. Near the anal end of the digestive tube and on the left side of the madreporic canal is a branching coecum, or pouch, called the "respiratory tree."

II. *The Water-vascular System.*

1. A funnel-shaped tube leads from the madreporic plate downward to the under side. This is the

madreporic canal. Its walls contain hard, granular bodies of a calcareous nature, from which it is sometimes called the "sand canal."

2. This connects at its lower end with a circular tube which runs around the mouth a short distance from it, in the membrane which extends from the mouth to the surrounding hard parts of the floor. This is the *circumoral canal*, and is best seen from the outside.
3. From this circumoral canal branch five canals which run along the central line of the ambulacral areas between the ambulacra on the outside of the bony floor of the rays. These are the *ambulacral canals.*
4. The ambulacra are connected with these canals by short *lateral canals.*
5. Within the cavity of the ray are numerous pear-shaped sacs projecting upward into the ray. These are the *ampullæ*, and are also connected with the lateral canals through the floor of the ray.
6. Note the alternate arrangement of both the ambulacra and ampullæ in two rows on each side of the central line of the ambulacral area.

III. *The Blood-vascular System.* Along with the madreporic canal is a membranous sac or tube, the *heart*, whose pulsations may be seen in a star-fish which has been opened while alive. Several other minute vessels are found in various parts of the body. These can be traced only by microscopic examination of sections made for that purpose.

IV. *The Reproductive System.* There is a pair of organs in a grape-like form suspended from the angle

of each two rays so that one of each pair of clusters hangs in each ray. These consist of globular bodies connected with a tube which opens through the crust at the angle of the rays. The two tubes have a common orifice for both clusters. The *testes* and *ovaries* do not differ in appearance, save slightly in color, in the breeding season.

V. *The Nervous System* of the star-fish must be studied upon the outside of the animal. A whitish, circular ridge around the mouth, and a short distance from it, and five ridges running along the centre of the ambulacral areas mark the location of the system. This lies along the main path of the water-vascular canals, and consists of the following parts: —

1. Five masses of nerve tissue at the junction of the circumoral ridge with the ambulacral ridge. These are the *ganglia*, or masses of nerve cells.
2. The *circumoral nerve ring.*
3. The *ambulacral nerve.*
4. This terminates at the end of the ray in a pigment spot constituting a *sense organ* called an "eye spot."

C. *Minute Structure.* Cut a ray across near the largest part and examine the section.

I. The outer crust or wall is composed of: —

1. The outer layer, a tough membrane of epithelial tissue covering the whole animal except the spines.
2. Beneath this and imbedded in connective tissue are certain hard bodies, the *calcareous ossicles.* These are arranged as follows: —
   a. Two of these are joined by their adjacent ends in the central line of the ambulacral area of

the ray at an obtuse angle. These are the *ambulacral ossicles.*

b. Adjacent to the outer ends of these ossicles are the ossicles of the ambulacral border. To these are attached the spines of this area.

c. In the lateral and aboral region are numerous ossicles at unequal intervals, also supporting the spines of the region.

3. The body wall is lined on the inside with a thin layer of *peritoneal epithelium.* Several modifications of this layer occur.

a. It is pushed out through the wall to form the lining of the aboral tentacles.

b. It is folded inward on the aboral side to enclose the clusters of hepatic coeca which are thus suspended from the aboral wall.

II. In this cross-section study the arrangement of the water-vascular system in connection with the floor of the ray.

1. In the angle of the ambulacral groove is the small ambulacral canal in transverse-section.
2. The lateral canal and its connection with the ambulacrum and ampulla may be discovered by a little patient searching.
3. Note the arrangement of the ambulacra on opposite sides of the ambulacral canal and of the two adjacent ambulacra on the same side.
4. Just below the ambulacral canal will be seen the cross-section of the ambulacral nerve.

III. Separate the upper and under crusts of a ray by cutting along the sides, and soak each in hot potash until the hard frame-work is nearly ready to drop apart, and then study the arrangement of the ossicles.

1. In the upper surface their irregular arrangement.
2. In the under surface notice: —
   a. The form and arrangement of ambulacral ossicles.
   b. The structure and arrangement of the openings through which the necks of the ampullæ passed.
   c. The arrangement of the ossicles which form the border of the ambulacral area, and their mode of union with the ambulacral ossicles.

D. *Microscopic Structure.* Make sections of a ray that has been soaked in acid to dissolve the lime salts, in the same manner as directed for the hydra and sponge. After staining and mounting, examine for the minute structure of the following parts: —

1. The ambulacral canal and its surrounding tissues, viz: —
   a. The cellular wall of the canal.
   b. The connective tissue surrounding it.
   c. The short fibres of muscular tissue which unite the upper ends of the ambulacral ossicles.
   d. The longer muscular fibres which run across from ossicle to ossicle below the canal. Explain the action of these two muscles.
   e. Below the canal and muscles is an irregular space called the *perihæmal* canal. Within this canal are the small blood-vessels.
2. The portion already referred to as the cross-section of the nervous system consists of two layers.
   a. The outer and thicker layer is surface epithelium, possibly not functionary as nervous matter.
   b. The inner, thin layer is supposed to be the true nerve cells.

3. Examine the sections of the ambulacra that occur. Several sections may be necessary to make out all the points mentioned. The ambulacrum is made up of the following tissues: —

a. An inner layer of longitudinal muscles.
b. An outer layer of transverse circular muscles.
c. Short muscles at the distal end which pass obliquely to the centre of disk at the end. The contraction of these muscles raises the centre and enables the star-fish to hold very firmly with this "sucking disk." The ambulacrum will often be torn off before the disk will loosen its hold.

4. Some of the sections will probably be cut so as to show the tubes leading from the ambulacral canal to the ambulacra and ampullæ.
5. Look also for vertical sections of the ampullæ and observe their structure.

E. *Comparison.* It will be interesting to compare a sea-urchin shell with the crust of a star-fish; and note especially: —

1. The arrangement of the ambulacral areas.
2. The position of reproduction openings and openings for the sense organs.
3. The arrangement of the ambulacral plates.
4. The arrangement of the plates which border the ambulacral area, here called interambulacral plates.

EMBRYOLOGY. — Both ova and spermatozoa are set free at maturity, and the ova are fertilized in the water. In mid-summer star-fish may be found in which the

sexual products are escaping. The ova are of a yellowish-brown color and the spermatozoa of milky-white. If some of the ova be taken up in a pipette and placed in fresh sea-water, they will be seen to be minute spherical bodies with a distinguishable germinal vesicle. The spermatozoa are exceedingly minute, distinguishable with high power of the microscope as rounded body or head, with a very long and slender, actively vibrating tail. Put some of the spermatozoa in the vessel which contains the ova. If some of the ova be examined, in a few minutes spermatozoa will be found clinging to the ovum. One of these penetrates the ovum and unites with its protoplasm. About an hour after fertilization ova may be found in which the protoplasm has divided into two cells, and in another hour some will consist of four cells. This process of segmentation goes on until the globular mass consists of numerous cells arranged in a single layer enclosing a cavity so as to form a hollow sphere. This is called the *blastophere*, and the layer of cells the *blastoderm*. The cavity is the *segmentation* cavity. One side of this layer of cells pushes inward so as to form a depression on the surface. This process is called *invagination*, and continues until a sac-like cavity is formed, which is the beginning of the digestive cavity. The cells are now arranged in two layers: the cells which still remain external form the *ectoderm* and the invaginated cells the *endoderm*. From the inner sides of the endoderm cells other cells arise and become free in the segmentation cavity forming the *mesoderm* cells. The ectoderm cells develop cilia; the embryo escapes from the egg-membrane and moves freely in the water.

This is called the *gastrula* stage of the embryo star-fish.[1] Compare this method of forming the gastrula with that of hydra.

The star-fish is a representative of the

BRANCH **ECHINODERMATA.** These are animals with a leathery or hardened crust which incloses a distinct body cavity through which the alimentary canal passes, and from which it is shut off, opening externally by an oral and an anal opening. A distinct nervous system, permanent reproductive organs, a complex water-vascular system, and a very primitive blood-vascular system also mark the advanced grade of their bodily structures. All the organs are arranged on a radial plan, with only slight occasional traces of any tendency to a bilateral symmetry of parts.

Class **Crinoidea** includes forms borne on stems with the mouth opening upward and surrounded with radiating arms, giving them a plant-like appearance. Most of these are fossil. They are the crinoids or "sea-lilies."

Class **Asteroidea** includes free-moving animals of a star-like form, and more or less flattened body. These are the "brittle-stars" and star-fishes.

Class **Echinoidea** includes spherical or disc-shaped forms with hard shell, the ambulacral areas extending to the dorsal side, and spines articulated with the hard shell. These are the sea-urchins.

Class **Holothurioidea** includes forms more or less elongated in the direction of the line from mouth to anus, possessed of a leathery covering and a circle of tentacles around the mouth. Here belong the "sea-cucumbers" and Synapta.

[1] For the further development of the larva of the star-fish see Brooks' Zoölogy.

CHAPTER XVI.

THE EARTH-WORM (*Lumbricus agricola*, Hoffm.).

SEVERAL distinct species of earth-worm exist, but the one to which the above name has been given is the most abundant. Large worms should be collected for study, and if they are to be needed when the ground is frozen they may be kept in vessels of earth rich in decaying vegetable matter. In this way they may be kept for several months in a good condition. The specimens being at hand, study them according to the following scheme.

MORPHOLOGY. — A. *External Anatomy.* Place a live worm upon a flat surface and watch its movements and form.

I. Observe the difference between the two ends of the body, showing longitudinal differentiation. This has been happily termed a *fore-and-aft* form.

1. The *anterior* end tapers gradually from about one third of the length of the body to the tip.
2. The *posterior* end does not taper but ends rather abruptly, retaining its full size to near the end.

II. The animal moves with one side habitually upward and a vertical plane through the length of the body would divide it into two similar parts representing the right and left halves of the body. This arrangement of parts is termed *bilateral symmetry*, and is a usual accompaniment of a fore-and-aft structure.

1. The upper, or *dorsal*, side of the body is usually slightly darker than the other, and through the nearly transparent body wall the dorsal blood vessel can generally be clearly distinguished.
2. The under, or *ventral*, side is shown by its light color.

III. The body is made up of rings or segments called *somites*.

1. Each of these somites except a few at the anterior end is provided with four pairs of spines, or *setæ*, the points of which can be seen projecting through the skin on the ventral surface.

   a. The outer pair are to be found nearly at the border of the ventral surface.

   b. The inner pair are between these and about twice as far from each other as they are from the outer pair.

These spines are provided with muscles, and can be directed either backward or forward. In this way they can be used at pleasure by the animal as a means of progression. Watch the movements of the animal and observe how they aid him in locomotion.

IV. After killing the worm by placing it for a short time in a vapor of ether examine it more minutely for the following anatomical features: —

1. In the centre of the anterior somite is the *oral* opening, or mouth, above which is the projecting lip, or *prostomium*.
2. On the ventral surface of three or more somites, about the eighth to the tenth, will be found gland-like prominences. These are adhesive organs used in copulation.

3. On the ventral side of the fourteenth somite and between the inner sets of setæ may usually be found the small external openings of the *oviducts*, the tubes that lead from the ovaries.
4. On the ventral side of the fifteenth somite are the openings of the *vasa differentia*, or sperm ducts, tubes that lead from the testes.
5. Several somites near the thirtieth usually form a somewhat enlarged ring in which the distinction of the somites is not clearly discernible. This is the *clitellus* or girdle, and is a thickened portion of the skin which at the time of producing eggs, becomes loosened, and is slipped off to form the egg capsule.

B. *Internal Anatomy.* Place a killed specimen upon the wax surface of the dissecting pan, dorsal side up, and with a pair of sharp-pointed scissors cut just through the thin body along the middle of the dorsal side from near the anterior to the posterior end, and pin the edges of the cut wall out upon the wax. Note the transverse partitions which partly divide the body cavity into sections corresponding with the somites. These partitions serve also to retain the other organs in place.

I. *The Digestive System.* This consists of a distinct tube, — the *alimentary canal*, running the whole length of the body, having the *oral* opening in the first somite and the *anal* opening in the last somite. The following parts may be distinguished, viz: —

1. The somewhat enlarged portion immediately behind the mouth, called the *pharynx*.
2. A smaller portion for about six to eight somites called the *œsophagus*.

3. An abrupt enlargement at the end of the œsophagus, forming the first division of the stomach, called the *crop*.
4. Another division of about the same size immediately behind the crop, called the *gizzard*.
5. The *intestine*, extending from the stomach to near the anus. Observe the outline of this tube.
6. A short and less baggy portion at the end called the *rectum*, which terminates in the anus.

II. *The Circulatory System*. 1. Lying directly upon the alimentary canal is the *dorsal trunk* of the circulatory apparatus.

2. From this the *transverse trunks* branch on either side throughout nearly the entire length of the canal.
3. By pushing the alimentary canal to one side the *ventral trunk* may be seen to lie just beneath it. This trunk is connected with the dorsal by means of the transverse trunks.

III. *The Reproductive Organs*. Carefully remove the alimentary canal except the anterior portion, when the following can be made out, viz: —

1. On either side of the œsophagus at the tenth and eleventh somites are seen the *testes*. These are three pair of white organs coming out from beneath the œsophagus. The anterior pair are smaller than the others, and are joined with the second pair.
2. Under the testes on each side of the middle line are two minute tubes with funnel-shaped mouths. Those on the same side unite just behind the posterior testes and form a single

vas deferens, which passes back to the fifteenth somite, where it opens externally as indicated above. A lens will be required to find these.

3. At the junction of the ninth and tenth, and also of the tenth and eleventh somites, on each side of the central line of the floor of the body cavity, a pear-shaped white body, the *seminal receptacle*. These receive the mass of spermatozoa called the semen at the time of copulation, and supply it to the egg capsule when the ova are deposited.
4. In the thirteenth somite, not far from the centre, will be found two small organs, the *ovaries*, in which the ova are produced.
5. In the fourteenth somite are two short, funnel-shaped tubes, the oviducts, the small end of which opens on the outside of this somite as mentioned above.
6. Animals in which both testes and ovaries are found in the same individual are said to be *hermaphrodite* or *bisexual* in distinction from the *unisexual* animals in which these organs occur in separate individuals.
7. When the ova are matured they are set free from the ovaries and pass out through the opening of the oviduct. At this time the thickened skin of the clitellus is loosed by the secretion of a mucous fluid underneath it, and is slipped forward, receiving as it passes the fifteenth and tenth somites the ova from the oviducts and the spermatozoa from the seminal receptacles, and when it slips off at the anterior end the ends become constricted, and form the egg capsule.

Fertilization therefore occurs within the capsule, where also the early development takes place. Although the earth-worm is hermaphrodite, copulation occurs so that the ova of one animal are fertilized by the spermatozoa of another. This, and the development of the ova, occurs during May and June.

IV. *The Excretory Organs.* These are a series of glandular organs, two in each somite except the first few. Each of these organs, which is called a ***nephridium***, consists of the following parts: —

1. A *funnel-shaped* inner end lying free in the posterior part of each somite.
2. This is followed by a very delicate ***tubular*** portion, which penetrates the partition and lies mostly in the next somite, where it is considerably convoluted upon itself and lined with active cilia.
3. The ***glandular*** portion, somewhat larger than the previous, in the walls of which urea is probably secreted.
4. The much larger ***muscular*** portion, which probably serves as a sort of reservoir, or bladder, for storing up the excreted matter until it is passed out from the body.
5. This portion rapidly contracts and ends by an opening through the external wall of the body on the ventral side of the somite, not far from the centre.

These organs are richly supplied with blood-vessels, so that the waste matter is removed from the blood by them instead of through the skin as in the simpler forms of animals we have studied.

V. *The Nervous System.* This consists of a series of ganglia, so united as to form a central cord from which nerves are distributed to all parts of the body. The worm, still pinned out upon the wax tablet, should be covered with clean water. The relation of the several parts may then be made out as follows: —

1. On the upper side of the thin pharynx, immediately behind the mouth, may be found a double mass of white tissue, the *cerebral ganglion*, which presages the brain of higher animals. From each of the masses of this ganglion a nerve runs forward to distribute its fibres to the anterior end of the body. From the size of these nerves, as compared with the area of the body to which they are distributed, one would infer that this portion is more perfectly supplied with nerves than others, which is undoubtedly true.
2. From each side of this ganglion a nerve runs downward beside the pharynx. These constitute the *pharyngeal commissures*, and after sending out minute nerves to the walls of the pharynx they unite below the pharynx in the first *ventral ganglion*.
3. The ganglion last mentioned is the first of a series of similar nerve masses, one in each somite, the *ventral ganglia*, which lie in the centre of the floor of the body cavity. These are connected by a mass of commissures of smaller diameter, so that the whole constitutes what is called the *ventral nerve cord*.
4. From each ganglion a pair of nerves is sent out to the contiguous parts of the body.

HISTOLOGY. — Earth-worms may be kept for some days in a flat-bottomed dish, in which is a very thin layer of water, sufficient to keep the skin moist but not to cover the worm, in order that they may get rid of the earth which is found in the intestine. This is greatly facilitated by placing in the dish shreds of filter paper completely reduced to fibres, which the worms swallow, and thus cleanse the intestine. They should then be killed in 30 per cent alcohol and at once straightened. Then place them in 50 per cent, 70 per cent, and strong alcohol successively for several hours each, until the worms are hardened. From strong alcohol they should be soaked and imbedded in celloidin and cut into thin sections. The sections should be assorted by the regions of special organs, stained with eosin or some other staining-fluid, cleaned, and mounted in balsam for study. These sections should be examined first with a low power of the microscope, and a sketch of the general arrangement of parts made, and afterward with a high power for the details of structure.

I. *The Body-Wall.* This is composed of several layers.

1. The thin layer on the outside with no traces of cellular structure constitutes the *cuticle*. This is thickly beset with pores. Through these exudes a slimy mucus when the animal is handled.
2. Immediately beneath this cuticle is a layer of cells elongated at right angles to the surface and thickly packed together. These are *columnar epithelium* cells, and constitute the *hypodermis*, or true skin.

3. A thick layer of muscular fibres running round the body lies under the thin hypodermis. These constitute the *transverse muscular layer.*
4. A still thicker layer of muscular fibres, shown in cross-section and running lengthwise of the body, constitutes the *longitudinal muscular layer.*
5. A very delicate layer of *peritoneal epithelium* lines the inside of the body-wall. This layer consists of flattened cells.
6. In some of the sections the setæ will be seen. Examine one of these sections and observe —
   a. The location in four pairs on the ventral surface.
   b. The muscles which are attached to their inner ends, by which they are directed according to the will of the animal. Explain locomotion by means of these.

II. *The Alimentary Canal* occupying the central portion of the body cavity.

1. The appearance of this will depend upon the region of the body from which it is taken.
   a. In the œsophagus it is a laterally flattened ring.
   b. Through the crop or gizzard it consists of a vertically flattened ring, much larger than in the œsophagus.
   c. Through the intestine there is a deep infolding of the dorsal side, forming the *typhosole.*
2. The wall of the alimentary canal consists of the following layers: —
   a. An outer layer of club-shaped greenish cells. These cells fill the cavity of the dorsal fold above which they are collected in a thick mass around the dorsal blood-vessel, to form the so-called *liver,* and may be regarded as

representing in a rudimentary way that organ in the higher animals.

b. Beneath this layer is a double ***muscular layer***, with a few scattered longitudinal fibres cut across, and a larger number of circular fibres. This is much thicker in the crop and gizzard.

c. Within this is the thin *vascular layer* containing many minute blood-vessels, surrounded with connective tissues.

d. Still within this is a layer of columnar epithelium cells, forming the inner portion of the thickness of the wall.

e. A delicate membrane lines the inner surface of the tube.

III. *The Circulatory System.* This appears as several distinct tubes seen in cross-section. Some of the sections will show the transverse branches.

1. On the dorsal side of the alimentary canal is the large *dorsal trunk.*
2. On the ventral side of the alimentary canal, and between it and the nerve cord, is the *ventral trunk.*
3. On the ventral side of the nerve cord is the *subneural vessel.*
4. On each side of the nerve cord and above the lateral nerves is a small vessel called the *superneural vessel.*
5. In some of the sections will be seen *transverse trunks* which connect the dorsal and ventral trunks, as well as small vessels which run to all parts of the body.

IV. *The Nerve Cord* lying upon the ventral portion of the body-wall, to which it is joined by connective

tissue. The cord is immediately surrounded by a delicate layer of *interlaced muscular fibres*, and all enclosed in a delicate membrane of *peritoneal epithelium.* The nerve tissue is made up of the following distinct portions: —

1. Certain pear-shaped cells lying in the outer portion of the cord, with their small ends turned inward. These are found mostly in the swollen or ganglionic portions of the cord, and upon the ventral side of the ganglion. In the cerebral ganglion these are found on the dorsal side.
2. The compact mass of nerve fibres in cross-section which make up the centre of the cord.
3. In those sections where the lateral nerves arise from the main cord it will be seen that they are composed of fibres alone.
4. On the dorsal side of the cord are seen three large *tubular* fibres, the centre one being the largest.

The earth-worm represents the large group of animals: —

BRANCH **VERMES**: These are animals with a distinct *fore-and-aft* polarity, and bilateral symmetry, distinct body cavity, completely separate digestive tube, with accessory organs, blood-vascular system, and well-developed nervous system. All parts arranged on the fore-and-aft plan.

Class **Platyhelminthes** includes worms with a flattened body, and only poorly developed blood-vascular and nervous system. Here belong the Turbellarians or "flat worms," the flukeworms, tape-worms, ribbon-worms, etc.

Class **Nemathelminthes** includes worms with round bodies, usually much elongated. Here belong the Trichinæ, pin-worms, vinegar eels, ascarids, etc.

Class **Annelida** includes worms with round body, divided into distinct somites, with well-developed blood-vascular and nervous system, and external setæ. Here belong the earth-worm, a few fresh-water worms, and an enormous number of marine worms.

Class **Hirudinia** includes flattened worms with clearly marked somites, well-developed blood-vascular and nervous systems and possessed of an anterior and a posterior sucking disk for purposes of locomotion. Here belong the leeches.

Class **Rotatoria** includes a group of minute worm-like animals, possessing a not very advanced condition of vascular and nervous systems, but clearly segmented body, and armed with a pair of ciliate disks on either side of the mouth. Here belong the Rotifers or wheel-animalcules.

CHAPTER XVII.

THE GRASSHOPPER (*Caloptenus spretus*).

IF the grasshopper is to be studied at a time when fresh specimens are not easily captured, they should be collected late in the summer, when they have reached maturity, and preserved in alcohol, care being taken that both males and females be included. Any of the large species will serve for study.

MORPHOLOGY. — A. *External Structure.* The grasshopper consists of an elongated and somewhat cylindrical *body*, to which are attached numerous parts called *appendages*. The body consists of a series of rings, or somites, seventeen in number, grouped in the three regions, the *head*, *thorax*, and *abdomen*.

I. *The Head* consists of four somites, which are, however, not easily distinguished. Note the following appendages, namely: —

1. The long antennæ on the anterior portion of the head. These are made of many joints, and are organs of sensation.
2. Just behind the antenna, on each side, is the *compound eye.* With the aid of a lens it will be seen that each eye is made up of a large number of small facets, each of which is a minute lens. Beside these compound eyes, the grasshopper has three simple eyes, or *ocelli.* One of these is situated between the bases of the

two antennæ, the other two above this, and between the upper front portion of the compound eyes. The portion of the head which bears them is called the *epicranium*, in front of which is an irregular portion called the *clypeus*.

3. Mouth organs.

a. Attached to the anterior edge of the clypeus is a broad and lobed flap, free at its outer edge. This is the *labrum*.

b. Just beneath this are two stout, block-like organs, with serrate inner edges. These are the *mandibles*.

c. Below the mândibles is another pair of flattened organs, the *maxillæ*. On the outer border of each maxilla is a curved cylindrical organ, called the *maxillary palpus*.

d. Below the maxillæ is still another pair of organs, which are united into one to form the *labium*.

e. On the upper or inner side of the labium, and attached to its base, is the *lingua*. These appendages, except the lingua, are supposed to represent three of the somites of which the head is composed.

II. *The Thorax* is composed of three somites, called the *pro-thorax*, *meso-thorax*, and *meta-thorax*.

Each somite, in both thorax and abdomen, is composed of three portions, the dorsal being called the *turgite*, the lateral the *pleurite*, and the ventral the *sternite*. The regions of the body which are made up of these parts are called respectively the *tergum*, *pleurum*, and *sternum*. The tergite is made up of

two pieces: the anterior, called the *scutum*, and the posterior, the *scutellum*.

1. The wings are borne upon the meso- and meta-thorax, each bearing one pair. The fore wings are long and narrow, and serve little purpose as organs of flight, but are used as covers for the true wings. The hinder wings are broad and thin, and are folded lengthwise, like a fan, under the wing-covers when not in use. Remove one wing of each pair, and examine its structure. It is composed of a frame of stiff ribs, between which is stretched the thin membrane of the wings.

2. There are three pairs of legs, one pair on each division of the thorax. Each leg consists of three portions. The stout portion nearest the body is the *femur*, next to which is the more slender *tibia*, and lastly the several-jointed *tarsus*, which ends in two claws. The femur is united to the body by two more or less distinct, but very short, joints which are sometimes nearly united. Of these, the one nearer the body is called the *coxa*, and the other the *trochanter*. Note carefully the external appearance of the legs.

III. *The Abdomen* consists of ten somites. The first of these forms only an incomplete ring, the dorsal portion being greatly broadened, and the remainder replaced by a portion of the meta-thorax, which projects backward to meet the second abdominal somite. The tenth somite is much modified for the bearing of the *ovipositors* of the female or the *copulatory organs* of the male.

1. The *auditory organ* is a sac, over which is stretched an oval resonant membrane, situated on the first abdominal somite.
2. On the second to the eighth somite in the pleurite, near its union with the sternite, will be found small openings, the *spiracles*, or breathing-pores. Each of these is connected with one of two tubes which run along the sides of the body. These tubes are called *tracheæ*, and by numerous branches convey air to all parts of the body.
3. The tenth somite differs much in the male and female. In the male the ventral portion is much larger than the dorsal. In the female, it bears four curved projections, which form the ovapositors.

B. *Internal Anatomy.* With a pair of fine-pointed scissors make an incision just through the dorsal crust, and a little to one side of the central line. Cut along the back, on one side of the central line, from the head to the end of the abdomen.

I. *Circulatory System.* Carefully raise the broadest side of the crust, and turn it over so as to see the inside.

1. Adhering to the inner side of the crust will be seen the *dorsal blood-vessel*, or *heart.* This can be pinned out upon the wax of the dissecting-pan.
2. Along the sides of this tube are small openings, called *ostia*, through which the blood enters the tube from the body cavity.
3. When the heart contracts, these openings close, and the blood is forced backward through the

aorta and its branches to the various organs of the body.

II. Pin the other side of the wall to the wax, and examine the *Reproductive Organs*.

1. If the specimen is a female, the whole body cavity will seem to be filled with the *ovaries*. The *ova* are oblong cylindrical bodies lying obliquely along the body cavity. Note carefully their form and relation one to another. At the dorsal end of each egg is a chain of smaller undeveloped eggs, which await the discharge of the mature egg for development. All these chains are connected at their dorsal end into one mass on each side, which constitutes the *ovary*. Beneath the ovaries are the much convoluted *oviducts*.
2. The *testes* occupy a similar position in the male, but are much smaller.

III. After removing the reproductive organs, the *Alimentary Canal* is left exposed. This consists of a tube running the whole length of the body, and is divided into the following well-marked divisions: —

1. The *mouth*, with its organs of prehension and mastication already examined.
2. The *œsophagus*, a narrow, short tube, extending from the mouth through the head and into the thorax.
3. This is followed by the *crop*, which is indicated by the abrupt enlargement of the tube. This occupies the most of the thorax.
4. At the posterior end of the crop are the six *gastric coeca*, in the shape of fusiform sacs arranged around the tube, and communicating

with it by openings at the largest part of the coecum. They secrete an alkaline digestive fluid.

5. The *stomach* occupies the anterior half of the abdomen. Between this and the following portion are situated
6. The *urinary tubes*, numerous minute tubes which open into the alimentary canal. They are arranged in ten clusters of twelve to fifteen tubes in each cluster.
7. The *ileum*, or large intestine, is short and much smaller than the stomach. This is followed by
8. The short *colon*, or small intestine, which is followed in turn by
9. The abruptly enlarged *rectum*. This, again, is surrounded by
10. The six *rectal glands*.
11. The *anus* terminates the alimentary canal, and is situated just below the supra-anal plate.
12. Immediately beneath the crop may be found the small *salivary glands*, which secrete the dark-colored saliva.

IV. *Respiratory System*. The respiratory system of the grasshopper consists of a set of tubes called *tracheæ*. Of these there are two running along the sides of the body. These may be found after the reproductive organs and alimentary canal have been removed. With these tubes the spiracles, already discovered in the study of the external anatomy, connect. The dilating and contracting of the walls of the abdomen changes the air in these tubes, and from them it is distributed by branches to all parts of the body. At frequent intervals, along these main trunks, are to be found sacs

connected with them, which are called the *trachæal vesicles*.

V. After removing the alimentary canal, care being taken to leave the œsophagus in place, find and study the arrangement of the *Nervous System*. This consists of the following portions: —

1. The *cephalic ganglion*, or brain, is a mass of nerve tissue lying in the front part of the head, between the eyes. From it nerves pass to the eyes, ocilli, and antennæ.
2. From the cephalic ganglion, a nerve trunk passes downward on each side of the œsophagus, and both unite below the œsophagus in a ganglion called the *infra-œsophageal ganglion*. The ring thus formed by these two nerve trunks is called the *circum-œsophageal ring*.
3. From the infra-œsophageal ganglion two nerve trunks pass backward on the floor of the body-cavity, and unite in three successive ganglia in the thoracic region, and a larger number in the abdominal. These constitute what is called the *ventral nerve cord*.
4. The *auditory nerve* arises from the third thoracic ganglion, and passes to the auditory sac previously described (A. III., 1). By means of the vibrating membrane which covers the sac, sounds are communicated to the nerve terminations.

The grasshopper represents a very large group of animals classed together as: —

BRANCH **ARTHROPODA**: These animals have a highly developed alimentary canal, circulatory, nervous, and reproductive

systems. The body is segmented, and provided with jointed appendages, the latter character suggesting the name.

Class **Crustacea** includes aquatic forms which breathe by means of gills, as crabs, lobsters, shrimps, etc.

Class **Arachnida** includes air-breathing arthropods with eight legs, as mites, ticks, and spiders.

Class **Onychophora** includes only one genus of many-footed worm-like forms, the Peripatus of South Africa.

Class **Myriapoda** includes the "thousand legs," and centipedes.

Class **Hexapoda** includes the insects, as butterflies, beetles, bugs, bees, grasshoppers, etc.

CHAPTER XVIII.

THE CLAM (*Anodonta fluviatilis*).

FOR the purposes of study, the common fresh-water clam is in some respects the best, but as it is not always easily obtained for the class, and the round clam or quahaug (Venus mercenaria) can usually be obtained in the markets of the eastern United States, the directions and description are so modified as to suit either. The fresh-water clam is found partly buried in the sandy bottoms of ponds and sluggish streams. Its location can generally be found by the shallow groove in the sand which it leaves as it crawls over the bottom. Specimens for study may be kept for a long time in a tank of water if it be frequently changed.

MORPHOLOGY. — A. *External Characters.* Distinguish the following parts: —

I. The *Shell* is composed of two equal *valves* united together externally by a very tough, hard *ligament.* The swelling in the region of this ligament is called the *umbo.* This ligament, or hinge, is on the dorsal side of the animal. Note in the shell the concentric lines which mark the various stages of growth of the shell. The umbo is nearer one end of the shell. This is the *anterior* end. The two valves are, therefore, upon the *right* and *left* sides of the animal. The ventral side and both ends of the shell are free.

II. If the living clam be placed in water (the quahaug must be placed in salt water, either natural or artificial) and left quiet for a time, the shell will open a short distance, revealing the borders of the *mantle* which lines the shell. If any small object be inserted carefully between the edges of the shell, the moment it touches the mantle the valves will be suddenly drawn tightly together.

III. At the posterior end of the shell for a short space the edges of the mantle are fringed, and stand away from one another so as to leave a double opening into the cavity of the mantle. This double opening is called the *siphon*. The lower is for the ingress of water and the upper for its egress. When the shell is open, the incurrent and excurrent streams of water may be detected. (The siphon in the quahaug is a considerable prolongation of the mantle, forming a black tube through which the water passes in and out.)

IV. On the anterior, or ventral, side is another place where the edges of the mantle are pushed apart for the protrusion of a thick, white, muscular organ of locomotion, the *foot*. When the clam wishes to move, this muscular foot is pushed out and forced into the sand. Then by twisting it slightly to one side and contracting the muscles by which it is attached to the shell, the shell is pulled forward a short distance through the sand.

B. *Internal Anatomy*. By a quick, but not too heavy blow with a hammer break the left valve of the shell. Remove the broken valve by carefully separating the mantle from the shell fragments and cutting the strong muscles which are attached to the anterior and posterior portions of the shell somewhat above the middle line. As soon as the muscles are cut, the portion

of the shell that includes the hinge will spring up of its own accord, thus showing the action of the tough black *ligament* by which the two valves are united along the dorsal border. Observe its nature and operation. How do the ligament and muscles operate? If this operation is successful the *mantle* will lie over the whole body as it rests on the right valve.

I. Observe the following muscles: —

1. Just in front of, and toward the ventral side from the beak orumbo is the stout *anterior adductor* muscle seen in cross-section.
2. Near the posterior end is .the equally strong *posterior adductor*.
3. Just behind and above the anterior adductor is a small muscle running obliquely downward. This is the *anterior retractor*, by which the animal is drawn into the dorsal portion of the shell before closing it.
4. Just behind and below the anterior adductor is another small muscle, the *protractor pedis*.
5. Just above and in front of the posterior adductor is a third small muscle, the *posterior retractor*.
6. The margin of the mantle also contains muscle-fibres in abundance.
7. The foot itself consists of a compact mass of firm muscular fibres, and is capable of great contraction and expansion.

The adductors pass directly from valve to valve and seem to close the shell. The retractors run from the shell near the attachment of the adductors and serve to draw the mass of the animal, but more particularly the foot, toward the dorsal side of the shell, and when used separately to move the shell forward or backward

upon the protruded foot. The protractor serves to push the foot forward.

II. Raise the ventral border of the mantle, and observe the *Respiratory Organs:*—

1. Two *gills* lie just beneath the mantle, free along their ventral margin but attached at their dorsal margin with the mantle to the body-walls. Note the structure of the two gills. Each gill consists of a series of loop-like bars, united to one another at certain points, between which are open spaces through which water may pass. These united bars form a plate-like organ, which is folded upon itself, thus possessing two *laminæ* which are united at their ventral edge. The bars are thickly covered with cilia. The outer lamina of each gill is attached at its dorsal side to the mantle and the inner lamina is attached by its dorsal edge to the corresponding edge of the outer lamina of the inner gill. The inner lamina of the inner gill is attached in its anterior portion to the outer surface of the foot, while its posterior portion is free but lies in close proximity to the corresponding lamina of the inner gill of the other side.
2. Follow the opening of the dorsal siphon forward under the adductor muscle and find the space above the gills called the *gill-chamber.* It is this chamber into which the water flows when it passes through the lamina of the gills, and from which it passes out through the excurrent siphon.

Make a diagram of a transverse section through the gills so as to show their structure and relation to the gill-chamber.

III. *Alimentary Canal.*

1. Just in front of the anterior margin of the gills, between them and the anterior adductor muscle are two triangular organs on each side united by their dorsal edge to the mantle and to one another. These are the *labial palpi.*
2. At the most anterior corner of these palpi, lying between the two palpi of one side and the two of the other side, also between the adductor and the foot, lies the *mouth*, a small opening often a little difficult to find. A beaded bristle may be inserted into the mouth, and thus the direction of the *œsophagus* determined.
3. Insert one point of the scissors into the dorsal siphon and cut its dorsal wall open for a short distance. The cut border may be turned aside and the *anus* will be found just above the posterior adductor muscle. If a bristle beaded with a bit of sealing wax be inserted in this it may be pushed forward a short distance into the *rectum* and *intestine* and may be left till a little later in the dissection.

IV. Just above the gill-chamber is the *Body Cavity* with its translucent wall, the outside layer of which is the continuation of the mantle. Cut open the wall of this cavity with great care, so that the organs within the cavity be not injured. This cavity is called the *perivisceral* cavity, and is filled with a thin fluid, the *perivisceral fluid.* It encloses the following organs: —

a. A long tube, running through the cavity from its anterior to its posterior extremity is the intestine. Push the beaded bristle which has been inserted into the anus forward

through the canal and watch its course as seen through the translucent wall.

b. At the point where the intestine enters the perivisceral cavity it emerges from a dark mass of glandular tissue which extends downward to the muscular portion of the foot. This is the *liver.* If a bristle be inserted into the mouth and pushed through the œsophagus it will soon become obstructed by the sudden bending of the tube as it enters the liver. The stomach consists of a narrow tube, which after several turns within the liver emerges from it into the body-cavity as the intestine.

V. In the anterior part of the perivisceral cavity is the *heart.* This consists of: —

1. The *ventricle* which is pierced by the intestine.
2. Two delicate funnel-shaped portions, the *auricles,* one on each side of the ventricle, with the small end opening into the ventricle.
3. There is a tube opening out of each end of the ventricle.
   a. That from the anterior end is above the intestine and is the *anterior aorta.*
   b. That on the posterior end is below the intestine, and is the *posterior aorta.*

The anterior aorta branches to the liver, stomach, anterior muscles, and foot; the posterior to the posterior muscles, gills, and mantle.

VI. In the posterior portion of the perivisceral cavity is the *renal organ,* sometimes called the organ of Bojanus, from its discoverer. This consists of two portions, the glandular, and non-glandular, lying in the posterior-ventral portion of the perivisceral cavity.

An opening from this organ leads to the gill-chamber, and so into the excurrent siphon.

VII. The *Reproductive Organs* are situated below and behind the liver. Both ova and spermatozoa are formed in the same animal, which is therefore said to be hermaphrodite. The ovaries and testes, associated as they are, are not easily distinguished. Openings from both into the gill-chamber exist, and in this chamber the ova are fertilized and development is partly carried on, until finally the young are expelled through the excurrent siphon.

VIII. The *Nervous System* consists of several ganglia which are united by nerve-cords, and from which nerves are distributed to the body.

1. The *cephalic ganglion* is a double mass, situated just behind the anterior-abductor muscle on either side of the mouth. The two masses are connected by a transverse nerve. These ganglia supply the nerves of the anterior organs.
2. From these a *lateral nerve* on each side runs backward to the *visceral ganglion* which in its turn supplies the posterior organs and most of the mantle.
3. From the cephalic ganglion another pair of nerve-cords runs to a ganglion in the foot called the *pedal* ganglion.

BRANCH **MOLLUSCOIDA**: Fixed animals with unsegmented bilateral bodies, enclosed in a cup-shaped sac or bivalve shell in which the valves are dorsal and ventral, nervous system very simple, and mouth-region provided with a pair of arms bearing ciliate tentacles or fringes.

Class **Bryozoa** includes forms growing mostly in colonies, each individual in a cup-shaped depression or cell. These are the so-called "Moss animals." Bugula, Alcyonidium and Crisia are some of the marine genera, and Plumutella and Piclomtella fresh-water genera.

Class **Brachiopoda** includes animals with a bivalve calcareous shell. They were once very abundant but are now found mostly as fossils.

Lingula and Terebratula are two of the living genera.

BRANCH **MOLLUSCA**: These are animals with a bi-lateral and unsegmented body, a single, median locomotive organ, bodies generally enclosed in a calcareous, bivalve or univalve shell.

Class **Placophora**: Molluscs with a shell composed of dorsal plates, a flattened, worm-like body without head. Here belong the Chitons.

Class **Lamellibranchiata** includes molluscs with a bivalve shell, no head, and a thin, laterally flattened foot, as clams and oysters.

Class **Scaphopoda** includes molluscs with a curved, conical, univalve shell, distinct head, and trilobed foot. The tooth-shell, Dentalium, belongs here.

Class **Gasteropoda** includes molluscs with a spiral, univalve shell, distinct head, and ventrally flattened foot. Here belong the snails and their allies in enormous numbers of genera.

Class **Pteropoda**: Molluscs with or without shell and with the foot transformed into two delicate wing-like projections. Clio and Hyalia are representative genera.

Class **Cephalopoda**: Molluscs with a distinct head armed in front with a circle of stout tentacles bearing sucking-disks. The squid, cuttle fish, devil fish, and nautilus are representative.

CHAPTER XIX.

THE COMMON FROG (*Rana virescens*).

FRESH specimens of the frog are best for study, but if it is more convenient for any reason to use them at a time when neither newly caught nor aquarium specimens can be secured, specimens preserved in strong alcohol answer most purposes, and for the muscles and nervous system these will in some respects be preferable to the others. Any species of Rana will answer equally well. The living frogs should be put in a small vessel which can be tightly closed. A small piece of sponge filled with ether is then suspended in the top of the vessel and the lid closed. In a short time the frogs may be taken out for use. To avoid the possible resuscitation of the animal a bit of cotton wet with ether may be placed in the throat.

MORPHOLOGY. — A. *External Form and Characters.* Make drawings of both dorsal and ventral views. Note the form of the body and its division rather obscurely into *head* and *trunk*.

I. The *Head* contains the following external organs:

1. The large *mouth* opening far back under the eyes.
2. Two small openings in the anterior part of the upper jaw. These are the *external nares*, or

nasal openings. Lift the upper jaw and find the *internal nares* in the roof of the mouth near the angle of the jaws.

3. The *eyes* are surrounded by folds of skin, which form the rudiments of lids, but which are capable of little motion. A thin membrane from beneath the under lid can be pulled up to cover the eye for protection against external objects.

4. Behind the eye is a circular disk, the *tympanum* or external membrane of the ear. Beneath this membrane is the cavity of the ear in which the nerve of hearing is distributed.

II. The *body* is joined to the head without any intervening neck and is largest in the anterior portion. Note: —

1. Two folds or ridges running nearly parallel the whole length of the body.

2. The color markings of the dorsal and ventral surface.

3. The anal opening on the upper posterior end of the body.

III. *The Limbs.* Each of these is made up of three portions, a proximal and distal joint and the foot. Observe the number of toes, four on the anterior and five on the posterior foot. The anterior legs are clumsy and of little use. The posterior are long and strong and the principal means of locomotion, on land by leaping, or swimming in water. For the latter purpose the toes are webbed. The posterior toe of the anterior foot of the male is larger, especially during the spawning season. It is inserted into a pit behind the fore leg of the female during copulation.

B. *Dissection.* Place the frog on its back on the dissecting board, and with the scissors make an incision in the skin of the ventral side. Cut the skin along the whole ventral surface from the anterior to the posterior end. It will be seen that the skin is free from the flesh beneath, except along certain lines. One of these runs along the ventral surface on either side of the centre. Another runs across the ventral surface between the anterior legs. Similar lines of attachment are found on the dorsal surface and correspond to ridges noted above. (II. 1.)

I. *General Arrangement of Internal Organs.* Immediately beneath the skin are the muscles of the body-wall. Note the long thin layer of muscle fibres that constitute the abdominal muscles. Cut this through from a point between the anterior legs to the posterior end and expose the internal organs or viscera.

1. In the most anterior portion of the opening thus made will be seen the somewhat triangular *heart* with its base toward the head. This will probably be still beating if dissection is performed soon after the frog is etherized.
2. Just behind and beneath the heart is the large dark *liver*, filling the cavity from side to side. Partly buried among the lobes of the liver will be found a dark-green sac which is the *gall* bladder. This is the reservoir in which the bile which is removed from the blood during its passage through the liver is stored previous to being poured into the digestive canal to aid in reducing the food to a fluid condition before it can be taken into the blood.
3. Just behind the liver will be found the intestine, that portion of the *alimentary canal* which fills

the abdominal region, and extends from the mouth to the anus.

4. Among the turns of the intestine toward the posterior portion is a dark ellipsoidal body about 5 mm. in its longest diameter, the spleen.
5. On either side of the intestine are the *reproductive organs*.
   a. In the males these consist of two yellow bodies a little longer than broad, and about the size of the spleen. These are the testes.
   b. In the female they consist of two irregular masses of a glandular organ occupying about the same position as the testes, but much larger. These are the *ovaries*. In the breeding season these distend the whole abdominal cavity with their matured black ova.
6. Underneath the reproductive organs are the *kidneys*, two long and rather irregular masses of a deep-red color.
7. Immediately in front of the most posterior part of the intestine is the *urinary bladder*.

II. *Digestive System*. In studying this it will be best to begin with the mouth.

1. The *mouth* consists of a wide opening bounded by two bony jaws opening vertically. Such a mouth is called *gnathostomatous*, as distinguished from a mouth with a circular opening, closed by a sphincter muscle. To this form of mouth the term *cyclostomatous* is applied.
2. Opening the mouth examine the edge of the bony jaws and find the minute *teeth* with which it is set. Note the form and attachment of these and the approximate number.

3. The *tongue* lies on the floor of the mouth and is attached at its anterior end. The posterior end is bilobed and free so that it can be thrown forward to catch food.
4. At the very front of the roof of the mouth in the bend of the jaw is an area in which are a large number of minute openings of the intermaxilary glands which secrete a mucous adhesive fluid which is brushed off by the tongue when it is projected forward for prehension.
5. In the roof of the mouth rather more than half way from the front are the two *internal nares*, or passages to the nasal cavities.
6. Still farther back and near the edge of the jaws are the *eustachian tubes*, or passages which connect with the drum of the ear.
7. Just below these near the angle of the lower jaw in the male are the passages which lead to the *resonant sacs*, the walls of which protrude on the sides of the head just behind the ear.
8. The posterior portion of the mouth contracts into the *œsophagus*, a narrow straight tube which leads to the stomach. A blunt searching-wire may be pushed down this tube till it reaches the stomach.
9. At the beginning of the œsophagus is the elongated slit-like *opening to the larynx* which will be described later.
10. The *stomach* consists of a sac formed by the enlargement of the æsophagus just behind the liver. The anterior end is the larger, and it tapers gradually into: —
11. The *intestine*. This is much bent upon itself

and its turns are fastened by a thin membrane which also attaches it to the dorsal walls of the body cavity. This is the *mesentery*. Follow its course throughout the whole length of the intestine and note how the blood-vessels run through it to the walls of the intestine. Near the beginning of the intestine the *gall duct*, leading from the gall sac to the intestine, enters the latter. Very near this duct in the mesentery will be found a somewhat indefinite glandular mass, — the *pancreas*. This also possesses ducts which lead to the gall duct, which is the common carrier for the secretions of the liver and pancreas.

12. Near its posterior end the alimentary canal suddenly expands into the *large intestine*.

13. On the ventral side of this portion will be found a loose and greatly distensible sac, the *urinary bladder*, which communicates by a short tube with the alimentary canal at the point where the large intestine ends.

14. The *cloaca*. This is the final region of the canal and serves as a common tube for the intestine, urinary, and reproductive organs.

15. This portion of the canal ends in the *anus*, which is closed by a sphincter muscle.

III. The various accessory organs named in the last section in connection with the alimentary canal, viz., the salivary glands, liver, and pancreas, are organs of *secretion*, *i. e.*, organs which extract from the blood certain fluids which are to be used again in the processes of the body. Those connected with the alimentary canal secrete digestive fluids.

IV. Another process of a similar sort and of great importance is the process of *excretion*, *i. e.*, the separation of waste material from the blood in order to remove it entirely from the body. Among the organs which perform this function are the *kidneys*. These are long, narrow, and somewhat irregular masses of a dark-red color lying on either side of the posterior portion of the body cavity. From each of these a tube called a *ureter* passes backward, and opens into the cloaca on its dorsal wall. The urinary bladder opens into the cloaca on its ventral side, to which it is closely attached.

V. *The Circulatory System* of the frog consists of a system of closed tubes, so that the blood does not escape into the body cavity, as in the previous types we have studied. The system consists of the following parts, namely: —

1. *The Heart* is a triangular body, situated, as already noted, in the anterior part of the body-cavity, and consists of: —
   a. The *ventricle*, occupying the posterior or apical half of the organ. This has thick muscular walls, the contraction of which pumps the blood over the whole body.
   b. In front of the ventricle the organ consists of *two auricles*, not readily distinguished from one another, but separated from the ventricle by a slight constriction or groove. The walls of the auricles are thin, requiring only sufficient contraction to send the blood which they receive to the ventricle. Of these auricles, the right receives the blood from the system, and the left from the respiratory organs.
2. *The Arteries*. Before studying the blood-vessels,

it will be better to cut a hole in the apex of the heart of a recently killed frog, and, inserting a canula, inject a red starch mass into the vessels. If successfully accomplished, the injection should fill the arteries with the injected mass, leaving the veins empty. A heavy pressure will inject the veins also, in which case they are not as easily distinguished from the arteries. If two specimens are injected, in one, the arteries only, and in the other, arteries and veins, they will be convenient to make comparisons.

a. The arterial system begins with a large tube, which opens from the anterior side of the ventricle, and passes along the ventral side of the auricle. This is called the *truncus arteriosus*, or *bulbus arteriosus*. This divides, just in front of the heart, into two tubes, each of which is separated by two septa into three passages, each passage becoming a separate artery.

b. Of these, the most anterior on each side is the *carotid arch*. This has a swelling not far from its origin, called the *carotid gland*, at which point it divides into two arteries, the *lingual artery*, which supplies the hyoid region and tongue, and *carotid artery*, which supplies the head.

c. The second division turns slightly dorsal and backward, forming the *systemic arch*. This runs backward, giving off several small divisions, namely, the *laryngeal*, *œsophageal*, and *occipito-cerebral arteries*, and unites with its

fellow, midway of the abdominal cavity, to form the *dorsal aorta*. Close to the point of union is given off the *mesenteric artery*, whose branches are distributed to the stomach, intestines, and spleen. A little farther back the *urino-genital* arteries pass on either side to the kidneys and reproductive organs. These are followed by the *lumbar* arteries, and the single *hæmorrhoidal* artery. Near the posterior end of the cavity the dorsal aorta divides into two branches, the *iliac* arteries, one running to each leg. The most important division of the iliac arteries are the *femoral* and *sciatic* arteries, the latter being the larger, and the continuation of the iliac artery.

d. The third, or *pulmo-cutaneous* arch, is just behind the systemic arch. It soon divides into two arteries, the *cutaneous* and *pulmonary*.

3. The *capillaries* are formed by the repeated division of the arteries until the tubes are so small that the blood corpuscles can pass through them only in single rows. These minute tubes form a complete network in every part of the body. If a frog be placed in a small muslin bag, one leg being allowed to protrude through the opening, and fastened to a "frog-board" with the web of the foot stretched out, so that it can be examined by transmitted light, with a low power of microscope, the capillaries can be seen with the blood coursing through them, the corpuscles in single file. Here the arteries may be recognized by the jerking motion of

the blood. These will be seen to divide into capillaries, which after a short distance again unite with other capillaries to form veins. If small tadpoles of the frog are at hand, one may be placed in a small amount of water, in a watch-glass, and the circulation in the tail studied at length.

4. The *veins* just described return the blood to the heart by several principal channels.

a. The blood from the viscera and the posterior portion of the body is collected and carried by the *posterior vena cava.* This enters a triangular sac which lies on the dorsal side of the auricles, at its posterior angle. This sac is called the *sinus venosus.*

b. At the anterior angles of the sac will be found the two *anterior vena cavas*, which collect the blood from the head, forelegs, and anterior portions of the body.

c. From the sinus venosus, the blood is poured into the *right auricle.*

d. The blood from the lungs is collected by the pulmonary veins, which unite into one vein and enter the *left auricle.* From both auricles the blood is sent to the single ventricle, to be again pumped to the capillaries as before. This is, of course, mixed impure and pure blood, since the blood that has been purified in the lungs, after being brought back to the left auricle, is poured into the same ventricle with the unpurified blood.

When the blood is again sent out from the ventricle, as we have seen above, a part of it

goes to the lungs to be oxidized, and returns by a short course to the heart. Of the remaining portion, that which goes to the mesenteric artery is returned through the liver, where the bile which has served its purpose of digestion is removed, and the blood returns to the heart. That which is carried to the kidneys is deprived of waste matter in them, and returns to the heart. The remaining portion is distributed to all the tissues of the body for the nourishment of the cells. In this course it also takes up the waste, worn-out material from the various tissues, and carries it to those organs which are to remove it from the blood and eliminate it from the system.

VI. *The Reproductive System.* The frog, like the grasshopper, is unisexual; that is, only one sort of sexual organs are found in any animal.

1. The female organs consist of the following parts:

a. The *ovaries*, already described. These consist of a mass of tissue in which, at all times, are numerous small germ-cells. In the breeding season large numbers of these become mature, and escape into the body cavity.

b. The *oviducts*, which lie along the sides of the body cavity, have a funnel-shaped opening at their anterior end. This opening is provided with cilia, which direct the free ova into the oviduct. As they pass along the oviduct, that tube secretes a layer of mucus, which encloses the ova and causes them to adhere together. When the ova escape into

the water, this mucus swells up into a jelly-like mass.

2. The male organs are the following: —
   a. The *testes* consist of masses of tissue, in which are formed sperm-cells which develop large quantities of *spermatozoa.*
   b. When the spermatozoa are mature, they escape from the testes, and pass out through the *vasa deferentia.*
3. During copulation, the ova from the female, and the spermatozoa from the male, are expelled into the water, and the ova are fertilized as in the other types studied. The changes which take place in the ovum of the frog are not easily followed in the early stages, on account of the opacity of the ovum. They pass through stages similar to those already described in the formation of the blastoderm of the sponge and star-fish. The later stages present some characteristic features which do not occur in the forms previously studied. Among the more important of these is the structure known as the *notochord.* After the formation of a germinal disc upon the food yolk of the embryo, a depression occurs in the ectoderm, called the *primitive groove.* This marks the beginning of the central nervous system. Immediately beneath this primitive groove, a mass of cells forms a longitudinal body known as the notochord. This shows traces of a division into segments. In the frog this is soon replaced by the axis of the vertebral column, and the notochord disappears.

VII. *The Skeleton*, or frame-work, of the frog consists of a series of hard structures called *bones*. Bone is a kind of tissue formed by the deposit of mineral matter by certain cells, which first form a cartilaginous *matrix*. The bones which make up the skeleton constitute a system of levers to which the *muscles* are attached for the purposes of locomotion. They are united by bands of elastic fibrous tissue called *ligaments*. For the study of the skeleton, the flesh should be thoroughly removed without severing the connection of the ligaments. If this be carefully done, and the skeleton allowed to dry, the bones will be held firmly in place by the ligaments, thus forming a natural skeleton. The skeleton may be divided, first, into *axis* and *appendages*.

1. *The skull* is the most anterior portion of the axis, and consists of the following bones: —
   - *a.* The *premaxillary* bones constitute the most anterior portion of the upper jaw, the posterior border being just beneath the exterior nares.
   - *b.* The *maxillary* bones occupy about two-thirds of the remaining border of the upper jaw, posterior to which is the short *quadrato-jugal* bone, with which it articulates.
   - *c.* The *mandible*, or lower jaw, consists of two lateral portions, each composed of four pieces.
   - *d.* Just behind the premaxillary bone, and separated from it by a narrow space, is the *nasal* bone. This is joined to its fellow in the centre, and reaches outward to unite by a cartilaginous union with the maxillary.
   - *e.* Just behind the nasal bone is the *sphenethemoid*,

which stretches across from one eye-socket to the other at the very anterior portion.

f. The *frontoparietals* lie between the eye-orbits, and continue backward to the: —

g. *Occipitals*, which surround the opening in the posterior end of the skull, called the *foramen magnum.*

h. External to the posterior end of the fronto-parietal, is a small, irregularly hexagonal bone called the *proötic.*

i. The *squamosa* bone consists of three arms; one of which unites with the proötic, another with the quadrato-jugal, and the third extends forward towards the maxillary, but does not unite with it.

The nasal, sphenethemoid, and fronto-parietal bones rest upon a basis of cartilage, which constitutes the roof of the nasal and brain cavities, and is continuous with a similar structure which forms the floor of these cavities. The base of the skull, or roof of the mouth, is composed of —

j. The *vomer*, lying just behind the premaxillary bone, and armed with several sharp teeth.

k. The *palatine*, which reaches from the middle line across to the maxillary.

l. The *parasphenoid*, which extends backward from the central union of the palatines to the posterior end of the skull, and

m. The *pterygoid*, a three-armed bone which joins the parasphenoid with the maxillary.

2. The portion of the axis behind the skull consists of nine joints, called *vertebræ.* Each of these

consists of a solid body, the centrum, on the dorsal side of which is an arch, through which passes the spinal cord. From this fact it is called the *neural* arch. From the centrum are *transverse processes* in most of the vertebræ, which represent the rudiments of a ventral arch, which in most vertebrates is complete for a number of vertebræ, and constitute the *hæmal arch*. In the frog, however, only those arches which support the limbs are complete.

a. The anterior vertebra, which is called the *atlas*, consists of a single arch without transverse processes.

b. The remaining eight vertebræ have transverse processes, which are larger in the third and fourth, with which the pectoral arch is connected, and the ninth, with which the pelvic arch is connected.

c. The *pectoral arch*, which supports the anterior limbs, consists of three bones, namely: a broad *scapula*, with which is connected at its dorsal end, a broad, thin cartilage, resting upon the transverse processes of the third and fourth vertebræ. Two bones join the ventral end of this scapula. The anterior of these is the *clavicle*, and the posterior the *corocoid*. These unite at their ventral end with the sternum.

d. The *sternum* consists of an anterior and posterior portion. The former is made up of the nearly cartilaginous *episternum*, and the bony *omosternum*. The latter consists of the

bony *sternum* proper, and the cartilaginous *xiphisternum*.

e. The *pelvic arch* supports the posterior limbs. A long curved bone, united at its anterior end with a transverse process of the ninth vertebra, is the *ilium*. The ilium broadens at its posterior end, to form the anterior half of the hip-socket. The posterior half is formed by two bones, which are so intimately united in the frog as not to be easily distinguishable. These are the *ischium*, on the dorsal, and the *pubis*, on the ventral side. These unite with the corresponding bones of the other side to complete the pelvic arch.

f. Between these two sets of bones, a long, slender bone projects backward from the ninth vertebra, in continuation of the back-bone. This is the *urostyle*, and represents the consolidated vertebræ of the tail of many other vertebrates.

3\. The anterior appendages consist of the following bones, namely: —

a. The *humerus* constitutes the first joint.

b. The *ulno-radius* is two bones united in one, and forms the second joint.

c. The *carpus* consists of six small bones, arranged in two rows of three each.

d. The *metacarpus* consists of five bones in the palm of the hand. The inner of these is much smaller than the other four, and forms the rudiments of the thumb, and is covered with the skin.

e. The four digits, beside the rudimentary first, each

consists of several bones called *phalanges;* the second and third of two each, the fourth and fifth of three each.

4. The posterior appendages are similarly constructed.
   a. The first joint is a single bone, the *femur.*
   b. The second joint, like the similar portion of the fore leg, consists of two bones consolidated into one, the *tibio-fibula.*
   c. The *tarsus* consists of two much elongated bones, which are sometimes called the *crus,* and four small bones beyond them. Two of them are by many anatomists regarded as the rudiments of an extra finger. They are pushed far to the inward side of the foot.
   d. The *meta-tarsus* consists of five long bones, which form the basis of the digits, as in the anterior foot.
   e. The *phalanges* are distributed as follows: in the first and second digits, two each; in the third and fifth, three each; and in the fourth, four.

VIII. *The muscular system.* For the study of the muscles, specimens should be put in alcohol for a few days in order to harden the muscles.

Cut open the skin on the ventral surface in the central line of the body from the tip of the lower jaw to the posterior end of the body. Note the lines along which the skin is attached to the body. The intermediate space is filled with lymph and constitutes what is called a *lymph sac,* of which more later. Having disconnected the skin from the body, observe the muscles thus laid bare.

Each muscle consists of a number of bundles of fibres

which are attached at one end, generally by elastic, non-contractile fibres, called a *tendon*, to a somewhat firm portion of the body. This is called the *origin* of the muscle. The other end is fixed generally also by a tendon to the portion to be moved, and this attachment is called its *insertion*. Only the superficial muscles are described in the following paragraphs.

1. Muscles of the ventral surface.

   a. Along the central line of the ventral surface is a straight narrow muscle running from the line of the fore legs to that of the hind legs, consisting of two equal bands, one on each side of the central line. This is the *rectus abdominis* (*musculus*).

   b. Arising along the central line of the anterior portion of the ventral surface and from the borders of the rectus in the posterior portion running outward and converging at the base of the fore leg are the fibres of the *pectoralis*. In the anterior portion may be distinguished the two somewhat distinct *sternal portions*, while the *abdominal* portion is still more clearly distinguished from the others. These all find their insertion upon the humerus near its head.

   c. Just in front of the anterior sternal portion of the pectoralis is the *sterno-radialis*. This has its origin along the central line of the neck and passing outward and slightly backward in front of the pectoralis is finally inserted near the head of the radio-ulnar bone.

   d. In front of the outer portions of the sterno-radialis, and taking its origin mainly from the

scapula and clavicle is the *deltoid*. This passes over the anterior side of the shoulder, and is inserted upon the humerus. This pulls the fore leg forward.

e. From the central line of the lower jaw the fibres of a thin broad muscle run outward to the jawbone. This is the *submaxillaris*. The posterior portion is somewhat separated from the rest, and constitutes the *hyoid portion* of the muscle.

f. Along the sides of the abdominal wall may be seen the *obliquus abdominis externus*, whose fibres run diagonally backward and inward under those of the rectus.

g. Beneath this muscle is an exceedingly thin layer of muscle fibres, running from the back around the body, partly forward and partly at right angles to the axis of the body, and uniting with the fibres of the rectus on the ventral side. This is the *obliquus abdominis internus*, and corresponds to the internus and transversus of the higher vertebrates.

2. Muscles of the dorsal surface.

a. A muscle having its origin along the middle line of the back, from just behind the eyes to a point somewhat behind the line of the fore legs, and converging to an insertion at the posterior end of the under jaw is the *depressor maxillæ*.

b. Raising the anterior corner of the preceding muscle will reveal another muscle, having its origin in the central line of the head and running under the posterior portion of the max-

illary bone to an insertion upon the ramus of the lower jaw. This is the *temporalis*, and its function is the closing of the mouth by the elevation of the lower jaw.

c. The muscle whose origin is along the central dorsal line from behind the depressor maxillæ, from whence its fibres converge to an insertion near the head of the humerus, is the *latissimus dorsi*, which serves to pull the fore leg backward.

d. Carefully remove the depressor and latissimus, and expose the narrow *longissimus dorsi*, having its origin on the anterior end of the urostyle, and its insertion at the posterior portion of the skull.

e. From the anterior half of the urostyle to the transverse process of the last vertebra, runs the *coccygeo-sacralis*.

f. Between the posterior half of the urostyle and the anterior half of the ilium is the *coccygeo-iliacus*.

g. The *ilio-lumbaris* originates at the anterior end of the ilium, and is inserted upon the transverse processes of the fourth to the seventh vertebræ.

h. The *gluteus* has its origin upon the posterior portion of the ilium and is inserted near the former.

3. Muscles of the anterior limbs.

a. The *triceps brachii* lies on the posterior side of the humerus, having its origin at three points, viz., —(1) at the posterior border of the scapula, (2) the anterior, and (3) the outer

surface of the humerus, while its insertion is upon the proximal end of the radio-ulnar bone. The *sterno-radialis* already described properly belongs to this region, corresponding to the biceps of the human arm.

b. In the second joint of leg are numerous *flexors* and *extensors* of the digits.

4. Muscles of the posterior limb.

a. The *sartorius* is a narrow, thin muscle lying obliquely across the ventral side of the leg, from the pelvis to the knee.

b. On the anterior side of the leg is the *triceps femoris*, having three points of origin, called internal, external, and long heads.

c. On the posterior side is the *rectus femoris*, having two nearly distinct portions; that on the ventral side being the *rectus internus major*, and that on the dorsal side the *rectus internus minor*.

d. Severing and raising the sartorius will reveal the adductors. The *adductor longus* is that which lies nearest the triceps, while the *adductor magnus* lies adjacent to and partly under the rectus. Between the adductor magnus and the rectus at their proximal ends lies the *adductor brevis*.

e. On the dorsal side of the leg will also be seen the triceps on the anterior and the rectus on the posterior side as already described. Between these are the *semimembranosus*, lying next the rectus, and the *biceps femoris* between it and the triceps. Between the heads of the triceps and the semimembranosus is the short *pyriformis*.

f. In the second joint of the leg the most conspicuous muscles are the *gastrocnemius*, the thick muscle on the posterior side of the leg, and the *tibialis posticus*, a small muscle lying between the gastrocnemius and the tibiofibula. On the anterior side three muscles may be easily identified, viz.: the *tibialis anticus* in the centre, the *extensor cruris* on the inner or ventral side, and the *peroneus* on the outer or dorsal side of the tibialis anticus.

For a more extensive study of the muscles the student is referred to Ecker's "Anatomy of the Frog."

IX. *The Nervous System* consists of two portions; the cerebro-spinal and the sympathetic systems. The former is the more important and the most easily traced. Remove the skin from the top of the head of a frog and with the point of a scalpel lift the posterior end of the fronto-parietal bone and the cartilage which immediately underlies it, taking great care not to disturb the brain which is thus exposed. After laying the whole brain bare it will be seen to consist of the following portions: —

1. The most anterior portion is termed the *prosencephalon* or fore-brain. It consists of two distinguishable portions.

a. The *olfactory lobes*, which are separated from the posterior portion by a slight constriction. The anterior end of these lobes contracts somewhat abruptly into the *olfactory nerves*, the fibres of which are distributed to the nasal cavity.

b. The *cerebral hemispheres*, which constitute the posterior and larger part of the prosencephalon.

2. Behind the prosencephalon and lying somewhat below it is the *thalmencephalon* or *optic thalmi.* In the anterior part of this, and just between the posterior ends of the cerebral hemispheres, is a small papilla which rises above the general surface of the thalmi. This is the *pineal gland.*
3. Next behind the thalmi are the large, rounded *optic lobes* or *mesencephalon* (mid-brain).
4. Behind these the rest of the brain consists of a long triangular portion, in which is a noticeable triangular depression. The ridge in front of this depression is the *cerebellum* or *metencephalon* (hind-brain), and the remainder is the *medulla oblongata,* or *myelencephalon* (after-brain). This tapers gradually until it leaves the skull and enters the canal of the spinal column, or back bone, when it is known as the *spinal cord.* By carefully dissecting away the dorsal portion of the arch which covers the cord it may be exposed for its whole length.
5. The *cranial nerves* are those which find their origin in that portion of the cerebro-spinal system which lies within the cranium, or skull. Of these the ones most readily traced should be identified by the student. There are ten pairs distinguished by anatomists.
   a. The *olfactory nerves* already distinguished (1. *a.*).
   b. The *optic nerves,* which take their origin from the under side of the optic thalmi, and after crossing one another pass to the eyes.
   c. The *oculo-motor* nerves spring from the under side of the brain, beneath the optic lobes, and are not easily found.

d. The *pathetic* nerves spring from the side of the medulla, a short distance behind the optic lobes.

e. The *trigeminal*, *facial*, and *auditory* nerves originate from the side of the medulla together.

f. Just behind the last-named group of nerves is another, which includes the *glosso-pharyngeal*, *pneumogastric*, and *spinal-accessory* nerves, also coming from the side of the medulla.

g. From the under side of the medulla in the region of the last two clusters is a small nerve called the *abducens*. This, like the oculo-motor, can be best seen when the brain is very carefully raised without breaking the nerves.

6. The *spinal nerves* are those which run from the the spinal cord. They are arranged in ten pairs and spring from the cord between the *vertebræ*. Each nerve arises in two roots, a dorsal and a ventral, arising from the corresponding portions of the spinal cord. Where the two roots unite, the dorsal root bears a small swelling or ganglion. These ganglia are covered by small glands. The spinal nerves may be best studied within the body cavity, where they may be found very readily.

a. The *first* pair of nerves, the *hypoglossal*, will be found in the very anterior portion of the body cavity. It is a small nerve, which supplies the muscles of the neck.

b. The *second* pair, or *brachial* nerves, are somewhat larger and run to the fore legs. The *third* pair more or less perfectly unite with

the second, but in this respect there is very great variation.

c. The *fourth*, *fifth* and *sixth* pairs supply branches to the abdominal walls and the viscera.

d. The *seventh*, *eighth*, *ninth*, and *tenth* pairs pass backward and unite to form a large trunk, the *lumbar plexus*, which passes to the leg in two branches, the larger of which is called the *sciatic* and the smaller the *femoral*.

MICROSCOPIC STRUCTURE of some of the tissues.

1. Place a drop of fresh blood from the frog on a slide and immediately cover it with a thin cover-glass. It is made up of a thin fluid, the *plasma*, in which are floating innumerable small bodies, the *blood corpuscles*.

These are of two kinds: the definitely shaped yellowish *red corpuscles*, so-called, and others of very variable shape and less color, the *white corpuscles*.

a. Notice the shape of the red corpuscles in different parts of the field, and ascertain the reason for this. Find the nucleus in each corpuscle.

b. After a time these will begin to collect in small clusters.

c. Expose a drop of blood to the air for a few moments and then handle it with a needle. The fibres of the plasma have stiffened in a stringy condition and entangled the corpuscles, forming a *clot*. How would this affect the flow of blood from wounds?

d. Note the less abundant white corpuscles, and watch for amœba-like movements in them.

e. Prick your own finger with a clean, bright needle and put a drop of the blood on the slide and examine it in a similar way. Note the difference in the shape of the corpuscles and their nucleation.

f. Let a drop of blood be allowed to dry on the slide, and place a very small grain of common table-salt and a drop of glacial acetic acid upon it. Cover it with a cover-glass, and heat the slide over a gas flame so that the acid will boil gently, and the coloring matter of the corpuscles will be dissolved and crystallize on the slide, making very beautiful microscopic objects.

2. Scrape the inner lining of a frog's mouth with the finger-nail or the handle of a scalpel. Put the scraping on a slide; let it dry a little so as to stick to the slide. Put a drop of some staining fluid, Bismarck brown, methyl blue, or hæmatoxylon on the slide for a few minutes and then wash it off with alcohol and examine it in glycerin. Scattered *epithelium cells* with deeply stained nuclei will be seen on the slide. Note their shape and manner of union. These are a very simple form of cells, which line the passages of the body. Their shape varies with their position. If cells be taken from the back part of the mouth they will probably be seen to possess cilia still in motion.

3. Take a piece of muscle from one of the large leg-muscles and examine its structure. It is made of *bundles* of *fibres*. Tease out one of these bundles with the needles and examine

it in glycerin under the high power of the microscope. Each fibre will be seen to be made up of still smaller fibres, called *fibrillæ*. Each fibrilla is enclosed in a delicate membrane called the *sarcolema*. Certain transverse markings can be seen also, called *striæ*. These are characteristic of voluntary muscles, but are sometimes found in involuntary muscles also. Stain a bit of muscular fibre with Bismarck brown as above, and there will be seen oval nuclei of the muscle-cells. The muscles are enormously elongated cells, which have the power to contract in length and thus shorten the muscle. How is this power illustrated by the movements of Amœba?

4. Let a piece of fresh spinal cord be hardened, imbedded in celloidin, and cut into thin, transverse slices. These may be stained with Bismarck brown, cleaned in chloroform, mounted in balsam, and then examined.

a. Note the form of the section. It is partly divided by fissures on the ventral and dorsal sides into two lateral halves. These are called the *lateral columns*.

b. An irregular cross-shaped darker portion occupies the centre of the section and extends two arms called *cornua* into each column. This darker portion is called the *gray matter*. Examine the region with the high power of the microscope, and there will be found numerous irregular cells more deeply stained than the rest of the tissue. These are the *nerve cells*. From the angles of these cells

nerve-filaments extend; some of them running out toward the origin of the spinal-nerves and joining others to make up the nerves.

c. The outer surrounding portion is called the *white matter*, and under the microscope will be seen to be made up of minute fibres, seen here in cross-section, each one having a more dense central or excentric spot, which marks the so-called *nerve axis.*

A more detailed study of the tissues of the frog would show that the whole body is made up of cells, many of them specially modified for some particular purpose.

BRANCH **HEMICHORDA.** Animals with a long, wormlike body, with a prominent proboscis, no external organ, a series of branchial slits on each side of the anterior portion of the body, fairly well-developed digestive, blood-vascular, and reproductive system, and very simple nervous system. The embryo shows relationship with the worms and echinoderms, but also develops a simple structure similar to the notochord of the frog embryo. The branchial slits also seem to correspond to similar structures in the adult fishes and embryonic forms of other higher animals. These points have led to the placing in a branch by itself the

Class **Enteropneusta**, represented by the genera Balanoglossus and Cephalodiscus.

BRANCH **UROCHORDA.** Animals with a sac-shaped or barrel-shaped body, the outer wall of which contains cellulose, a substance otherwise peculiar to the vegetal kingdom. The branchial cavity possesses two external openings, and out of it the mouth opens. The nervous system is

exceedingly simple, and the animal is usually sedentary. The larval form is free-moving and develops a notochord, which, however, subsequently disappears. The branch includes the animals of only the one

Class **Tunicata.** Genera: Appendicularia, Ascidia, Botryllus, Pyrosoma, Salpa, etc.

BRANCH **CEPHALOCHORDA.** Animals with an elongated, fish-like body, but without any head, and with a branchial sac similar to that of the larval tunicates. A notochord shows its relationship to the frog; but unlike the two previous forms, this is persistent. The mouth is near the anterior end of the body, but is not possessed of jaws. The branch includes only the

Class **Leptocardii,** which is represented by the single genus Amphioxus, the "lancelet," a small creature a little more than three centimetres long.

BRANCH **VERTEBRATA.** Animals with a cartilaginous or more often bony endoskeleton, the axis of which is composed of divisions called vertebræ, well-developed digestive, circulatory, respiratory, reproductive, and nervous system, and never more than two pairs of limbs. All forms develop a notochord, which is replaced by the centrum of the backbone.

Class **Marsipobranchii.** Vertebrates with a circular (cyclostomatous) mouth, six or seven gill-pouches, a caudal fin, and no limbs. Here belong the hags (Myxine) and lampreys (Petromyzon).

Class **Pisces.** Vertebrates with gnathostomatous mouth, paired fins, generally distinct dorsal, caudal, and anal unpaired fins. Here belong the fishes.

Class **Amphibia.** Vertebrates with well-developed limbs, breathing by gills in larval life, and lungs in the adult. These are the frogs, toads, and salamanders.

Class **Reptilia.** Vertebrates with well-developed limbs or none, always breathing by lungs, and generally covered by scales. Snakes, lizards, turtles, crocodiles, and alligators.

Class **Aves.** Vertebrates with one pair of limbs transformed into wings, warm blood, young hatched from eggs, body covered with feathers. Birds.

Class **Mammalia.** Warm-blooded vertebrates, generally producing their young alive, the egg having developed within the modified oviduct, and nourishing the young after birth by milk secreted by the mammary glands, generally with four limbs. Ant-eaters, kangaroos, rodents, bats, whales, cats, dogs, bears, monkeys, and man.

GENERAL CLASSIFICATION.

VEGETALIA.

PROTOPHYTA.
- Schizomycetes.
- Cyanophyceæ.

ZYGOPHYTA.
- Zoösporeæ.
- Conjugatæ.

OÖPHYTA.
- Volvocineæ.
- Edogonieæ.
- Cœloblasteæ.
- Fucaceæ.

CARPOPHYTA.
- Colochætæ.
- Floridæ.
- Ascomycetes.
- Basidomycetes.
- Characeæ.

BRYOPHYTA.
- Hepaticæ.
- Musci.

PTERIDOPHYTA.
- Equisetinæ.
- Filices.
- Lycopodiaceæ.

SPERMOPHYTA.
- Gymnospermæ.
- Angiospermæ.

ANIMALIA.

PROTOZOA.
- Mycetozoa.
- Rhizopoda.
- Infusoria.
- Gregaranida.

PORIFERA.
- Spongida.

CŒLENTERATA.
- Hydrozoa.
- Actinozoa.
- Ctenophora.

ECHINODERMATA.
- Crinoidea.
- Asteroidea.
- Echinoidea.
- Holothuroidea.

VERMES.
- Platyhelminthes.
- Nemathelmenthes.
- Rotatoria.
- Gaphyrea.
- Chætognatha.
- Annelida.
- Hirudinea.

ARTHROPODA.
- Crustacea.
- Onycaphora.
- Myriapoda.
- Arachnida.
- Hexapoda.

MOLLUSCOIDA.
- Bryozoa.
- Brachiopoda.

MOLLUSCA.
- Placophora.
- Lamellibranchiata.
- Scaphopoda.
- Gasteropoda.
- Pteropoda.
- Cephalopoda.

HEMICHORDA.
- Enteropneusta.

UROCHORDA.
- Tunicata.

CEPHALOCHORDA.
- Leptocardii.

VERTEBRATA.
- Marsipobranchii.
- Pisces.
- Amphibia.
- Reptilia.
- Aves.
- Mammalia.

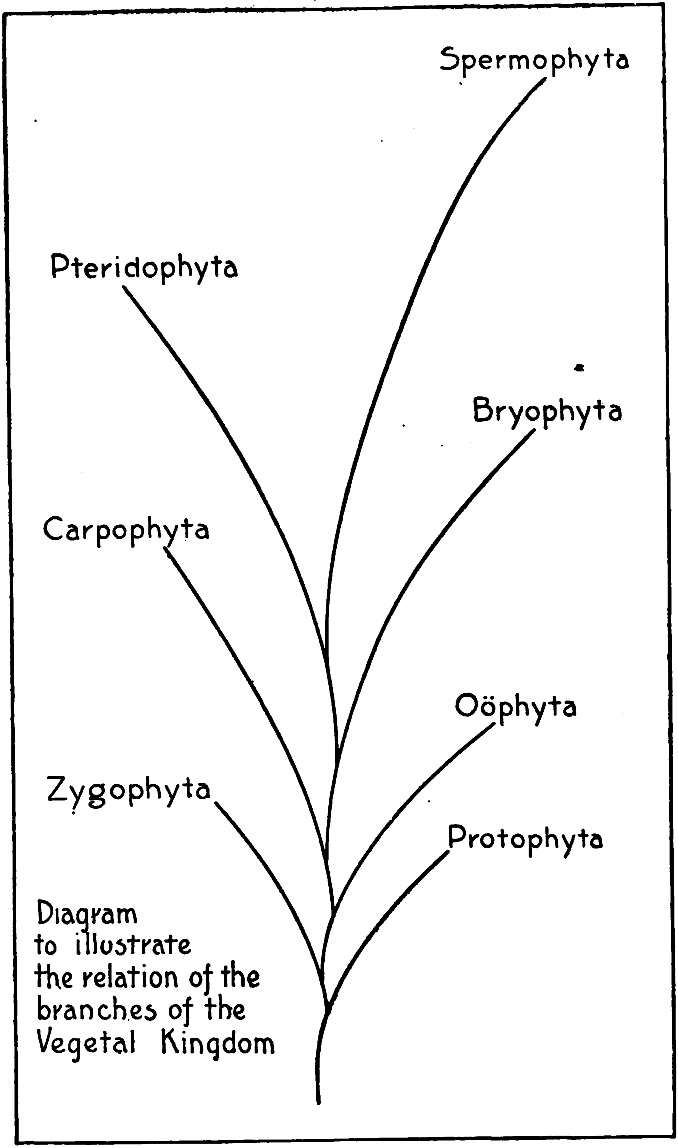
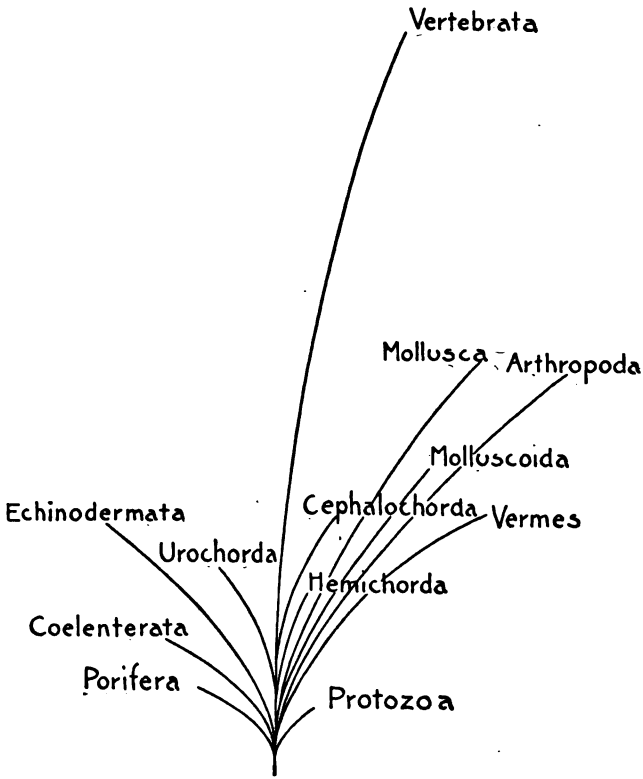

Spermophyta
Pteridophyta
Bryophyta
Carpophyta
Oöphyta
Zygophyta
Protophyta
Diagram
to illustrate
the relation of the
branches of the
Vegetal Kingdom

Diagram illustrating the relationship of the branches of the Animal Kingdom



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